NATIONAL BANK OF RWANDA
BANKI NKURU Y'U RWANDA

BNR ECONOMIC REVIEW

Vol. 13

August 2018

ISSN 2410-678 X

BNR Economic Review Vol. 13

ISSN 2410-678 X

BNR ECONOMIC REVIEW

Vol. 13

August 2018

Disclaimer

The views expressed in this review are those of the respective authors and not necessarily of the National Bank of Rwanda. Apart from any commercial purpose whatsoever, the reprint of the review or of its part is permitted.

Foreword

The bi-annual publication of the economic review is intended to avail information to the public on economic matters, focusing on features and challenges of the Rwandan economy. This 13th volume of BNR Economic Review consists of four papers, with topical issues related with improving the understanding of monetary policy challenges in Rwanda and in the region, and developing mechanisms to facilitate the transition towards a modern forward-looking monetary policy framework. The papers aim at providing concrete evidence-based analysis and policy recommendations that can help to improve the effectiveness of monetary policy in Rwanda.

The first paper analyzes the progress achieved by National Bank of Rwanda (BNR) in developing money market and identifies possible channels for monetary transmission mechanism as main prerequisites ahead of the adoption of a price-based monetary policy framework. The paper provides a descriptive analysis of money market, showing that a change in the policy rate has a significant impact on Rwanda's interbank rate, and that the difference between the policy and interbank rates narrows gradually. However, the study finds evidence of volatility transmission from the interbank rate to higher maturities.

The paper further assesses the transmission mechanism of monetary policy in Rwanda as results of recent financial reforms and financial innovation as well as improvement in monetary policy management by BNR. The empirical analysis shows that the link between repo rates as proxy of policy rate and interbank rates has improved in recent years due to good liquidity forecasting and management. In addition, the link between money market rates (interbank rates and Treasury bill rates) and deposit rates for different maturities is statically significant and has been improving in recent years. However, there is no clear link between money market rates and lending rates while the link between deposit rates and lending rates is significant. In addition, many of correlation coefficients are low compared to the average of low-income countries (LICs), indicating that interest rate channel remains weak in Rwanda.

The second paper investigates the link between inflation and Rwanda's economic growth by estimating the threshold level of inflation. As BNR switches to a forward-looking monetary policy framework, this investigation aims to guide monetary authorities in their endeavor to set a realistic inflation objective that is in line with sustainable national macroeconomic stability as well as the broad development policies and strategies. The results show that the threshold inflation level for Rwanda is 5.9%, which supports the EAC inflation ceiling of 8.0% and the BNR's band of 5±3%. The estimated threshold inflation level is *consistent with 9.0% growth in real GDP required to push the economy to high-income status.*

The remaining papers document two important functions of a forward-looking monetary policy at BNR, namely (i) the modeling and forecasting function, and (ii) the communication function. One paper elucidates econometric models used for forecasting inflation at BNR. It documents that non-structural models such as ARIMA and State-Space models are used for short-term forecasting, while the Forecasting and Policy Analysis System (FPAS), a small-scale New-Keynesian macroeconomic model, is used for medium-term projections. The power of non-structural models reduces in presence of shocks, whereas the FPAS performs well in terms of out-of-sample forecasting and building a consistent story for the whole economy.

The last paper in this volume reviews existing literature on the role of central banks communication in the effectiveness of monetary policy under forward-looking price-based policy framework. Reviewed evidence suggests that under forward-looking, price based monetary policy frameworks, central bank communication is indeed an important and powerful aspect of the central bank's toolkit since it has the ability to influence market expectations and enhance the transmission mechanism of monetary policy actions. The paper also attempts to reassess the effectiveness of BNR communication. The results suggest that indeed BNR communication helps to reduce volatility of interbank rates and exchange rates in Rwanda.

Comments and questions can be sent to the Director, Research Department on phitayezu@bnr.rw, KN 6 Avenue 4, P.O Box 531 Kigali-Rwanda.

RWANGOMBWA John

Governor

TABLE OF CONTENTS

REQUIREMENTS FOR USING INTEREST RATE AS AN OPERATING TARGET FOR MONETARY POLICY: THE CASE OF RWANDA

Thomas R. KIGABO[1] **Callixte KAMANZI**[2]

[1] Prof. Thomas R. Kigabo is the chief Economist and Executive Director of Monetary Policy and Research, National Bank of Rwanda.

[2] KAMANZI Callixte is the Economist in Research department, National Bank of Rwanda.

ABSTRACT

This paper aimed at analyzing the progress achieved by the National Bank of Rwanda in developing money market, and identifying possible channels for monetary transmission mechanism, as main prerequisites ahead of adopting price-based monetary policy framework.

In the first part of the paper, the money market analysis has indicated that over the years, the framework of monetary management derived from the strategic interventions has improved significantly. Thus, the Rwandan money market continues to evolve and grow, and efforts to remove impediments to financial intermediation are ongoing. The findings reveal that a change in the policy rate has a significant impact on Rwanda's interbank rate, and that the difference between the policy and interbank rates narrows gradually. However, we find evidence of volatility transmission from the interbank rate to higher maturities. In fact, changes in the policy rate may not have the intended effect on funding costs for longer-term maturities, if accompanied by increased volatility of the interbank rate. This suggests that the mitigation of volatility transmission from interbank rate to long-term maturity yields deserve consideration for policy decision. There is need of continued commitment to the interbank rate as an operational target, by creating a narrower corridor that would force a faster rate of convergence in interbank rates, reduces the persistence in volatility, and mitigate absolute volatility along the yield curve.

In the second part of the paper, we assessed the transmission mechanism of monetary policy in Rwanda as results of recent financial reforms and financial innovation as well as improvement in monetary policy management by the National Bank of Rwanda. The empirical analysis shows that the link between repo rates as proxy of policy rate and interbank rates has improved in recent years due to good liquidity forecasting and management. In addition, the link between money market rates (interbank rates and Treasury bill rates) and deposit rates for different maturities is statically significant and has been improving in recent years. However, there is no clear link between money market rates and lending rates while the link between deposit rates and lending rates is significant. In addition, many of correlation coefficients are low compared to the average of low-income countries (LICs), indicating that interest rate channel remains weak in Rwanda.

Key words: Money market, monetary policy, Rwanda**.**

JEL Classification: E43, E52, E58.

I. INTRODUCTION

The National Bank of Rwanda (BNR) implements its monetary policy under a monetary targeting regime since 1997. The monetary transmission mechanisms are set out from the quantity of monetary base (B) also called reserve money as an operational target and move towards inflation through the broad monetary aggregates (M3) as the intermediate target. In this framework, it is assumed that the money multiplier is stable and predictable, to ensure the controllability of M3 via reserve money and that the money demand function is stable to ensure a strong and reliable relationship between M3 and goal variables, such as prices.

A number of financial reforms was introduced since1995 in Rwanda, including the adoption of market-based mechanisms, coupled with financial sector liberalization and deregulation. The salient features of financial system reform program in Rwanda were interest rate liberalizations (i.e, lending and deposit rates have been freed from control), development of money market with progressive introduction of new instruments, and introduction of open market operation (OMO).These reforms allowed BNR to conduct monetary policy relying on market based instruments. The capital account was fully liberalized in 2009 and the exchange rate regime shifted from a fixed to a progressively more flexible regime.

In addition, different financial innovations have been introduced in the banking system in the last decade including the establishment of new financial institutions, extension of the banking sector's network and the introduction of new financial products such as automated teller machines, point of sales, as well as mobile and internet banking. Between 2011 and 2017, retail e- payment as percentage of GDP increased from 0.3% to 26.9%. The value of mobile money transactions increased from 51,024 to 1,384,686 million FRW, the value of Automatic Teller Machines (ATM) transactions increased to 493,038 in 2017 from 122,974 FRW millions in 2011, while the value of Point of Sales (POS) transactions increased from million FRW 6,438 to 68,994 in the same period.

Further, the capital market was created in 2008, and has been becoming progressively active since 2014 after BNR and the Ministry of Finance and Economic Planning decided to issue treasury bonds on a quarterly basis. Thus, capital market is becoming a new saving opportunities for non-bank financial institutions and households in Rwanda. As a result, the share of banks in T-bonds significantly reduced from 83.2% end 2012 to 35.8% in May 2018. The share of institutional investors increased to 41.8% in May 2018 from 11.0 % end 2012, while the share of retail investors increased from 5.7% to 8.7% in the same period.

These developments contributed to progressively weaken the link between M3 and the base money as well as between monetary aggregates and inflation. Indeed, Velocity and money multipliers have been subject to large fluctuations and experienced structural breaks (Kigabo and Mutuyimana, 2016). We have re-estimated the money demand function in Rwanda and tested its stability. Results of the estimation are presented in annex 1.

Two important findings need to be highlighted: (i) based on the theory of asset demand; we have tested if money demand in Rwanda is function of returns on other assets relative to expected return on money to capture recent developments in money market. Because the share of non-bank financial institutions and households in government securities has been increasing over the recent period, we have tested if the Treasury bill rates as opportunity cost of holding money and deposit rates as return on money are significant in the money demand function in Rwanda. Estimating the money demand function from 2000, we find that the difference between the two rates is not significant in the money demand function. However, the difference become significant when the money demand is estimated from 2009. This clearly indicates how Rwandan economic actors have become more rational in their portfolio management and how their decisions are progressively being influenced by the development in interest rates on available financial products. (ii) The mentioned changes have contributed to the instability of money demand in Rwanda since 2011 as indicated by CUSUM tests.

Due to these developments, BNR as well as all EAC central banks is planning to shift to price base monetary policy by end 2018, after a long period of preparation. In 2012, BNR adjusted the reserve money program by introducing more flexibility in the implementation of monetary policy by introducing a reserve money band of +-2% around a central reserve money target derived from the quantitative equation. This change contributed to more flexibility in money market rates, development of interbank market and limited volatility in money market rates. Indeed, by using reserve money operating targets, short-term interest rates often exhibited high volatility arising as operations were focused on achieving period-end quantitative targets.

In addition, BNR invested significantly in capacity building of its staff in the last 5 years, particularly in modeling and forecasting, liquidity forecasting and management as well as in policy communication, which are key requirements for the effectiveness of a price based monetary policy. An effective capacity to forecast liquidity developments in the system (that is, to forecast changes in the central bank's balance sheet) will allow the central bank to make informed decisions on the timing and size of its discretionary monetary operations. In turn, these operations will effectively steer liquidity in the system to its optimal level, and set up conditions for a smooth functioning of the market. Effective forecast of liquidity reduce interest rate volatility allowing the central bank to set a wider interest rate corridor (spread between its deposit standing facility and its lending standing facility) that would encourage interbank market trading.

In a price based monetary policy framework, central banks use interest rate as operating target to manage the overall liquidity in the economy. In that framework, the central bank rate signals the monetary policy stance and the liquidity in the money market is managed to align money market interest rates with the central bank rate. Thus, appropriate management of liquidity enables to preserve the signaling function of the monetary policy stance performed by money market interest rates.

The use of interest rate is key for a forward-looking monetary policy, because long-term interest rates are related to short-term rates through market expectations of future short-term rates. With a well-functioning interest rate channel, the monetary policy stance, reflected by the central bank rate has a forward-looking dimension.

Based on the above mentioned factors, the effectiveness of the price based monetary framework depends on a set of pre-requisites including a well-functioning and developed money market, a working monetary policy transmission mechanism, transparency and credibility trough communication, and strong capacity of central bank in modeling and forecasting.

The two first conditions are discussed in this paper while the other two requirements are discussed in separate papers. The rest of the paper is structured as follow: In the second section, we assess progress achieved by BNR in the development of money market in Rwanda. The assessment of monetary transmission mechanism is done in Section 3 before concluding the paper by proposing some policy recommendations.

II. Money market development in Rwanda

2.1. Money market instruments

Money market is defined as a market for short-term funds with maturities ranging from overnight to one year and includes financial instruments that are considered to be close substitutes of money. It provides an equilibrating mechanism for demand and supply of short-term funds and in the process provides an avenue for central bank intervention in influencing both the quantity and cost of liquidity in the financial system, consistent with the overall stance of monetary policy. Money market plays a central role in the monetary policy transmission mechanism by providing a key link in the operations of monetary policy to financial markets and ultimately, to the real economy (Mishkin, 2002).

The Rwandan money market was officially established on 12th August 1997, under the provisions of the BNR instruction No 02/97. The first money market operation took place on 12th September 1997, where the BNR intervened by mopping up excess liquidity in the banking sector. The money market constituted a foundation of the development of monetary policy instruments based on market forces and opened doors for BNR to implement open market operations and respond more efficiently to the market liquidity conditions. Following instruments are used in the money market in Rwanda: repo/reverse repo, Treasury Bills, standing Lending facility, overnight deposit facility, refinancing facility, and True repo.

A repurchase agreement (REPO) involves the acquisition of immediately available funds through the sale of securities with a simultaneous commitment to repurchase the same securities on a date, at a specified price. This is one of mostly effective tool in managing short-term liquidity in banking system. A reverse repo transaction is just the other side of a repo transaction, where securities are acquired with a simultaneous commitment to resell same security at a specified price at a specific time in the future.

In August 2008, the overnight facility and the 7-day auction were replaced by the REPO (Repurchase Agreement), whose operations take place every working day with a duration varying between 1 to 28 days, at competitive bids. On June 23rd 2010, BNR decided to revise down the repo maturity from 28 to 14 days. The new measure aimed at contributing to the improvement of the short-term yield curve shape as well as to separate maturities from different monetary instruments.

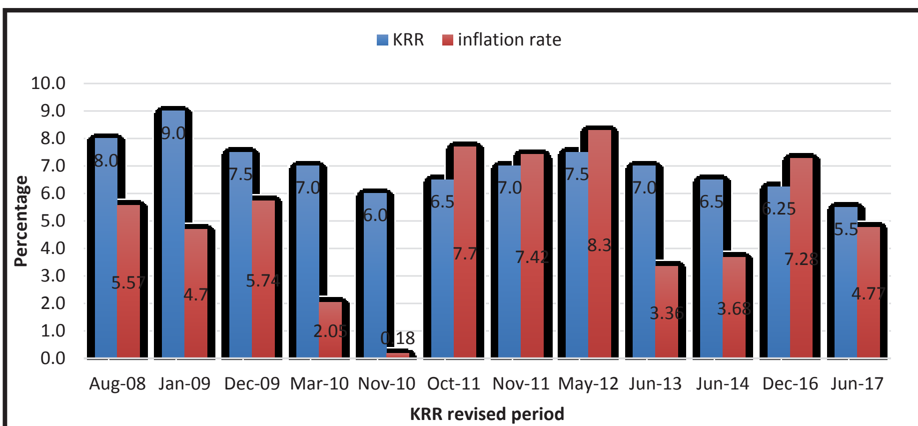
In 2012, the BNR revised the mechanism of intervention on money market using REPO by fixing the REPO/REVERSE repos maturity to seven (7) days from 14 days. The new measure aims at developing the inter-bank transactions and managing the liquidity efficiently, referring to persistent excess liquidity in all commercial banks that hinders the interbank market development. However, the BNR can, at its discretion, issue a REPO instrument of any maturity as need arises.

Based on the banking liquidity condition prevailing in 2008 and the expected trend in the near future, the BNR introduced a policy rate (the Key Repo Rate-KRR) and set it at 8% per annum and the width of the inter-bank interest rate corridor to 125 basis points (1.25%) below and above the key REPO rate. With that new policy, BNR money injection is done at a competition basis, the minimum interest rate being the ceiling of the "corridor". In a similar manner, it absorbs excess funds on a competition basis, the maximum interest rate being fixed at the floor of the "corridor".

The Monetary Policy Committee decided in December 2009 to use only the KRR as reference to borrow or to lend liquidity from/to the market. Since that period, the KRR is the Bank policy rate which indicates the maximum rate it mops up the excess liquidity from the banking system and the minimum rate it injects liquidity in the banking sector.

The KRR has been regularly reviewed by the monetary policy committee based on the forecast of inflation as well as the development in liquidity conditions.

Figure 1: Key repo rate (KRR) vs inflation rate.



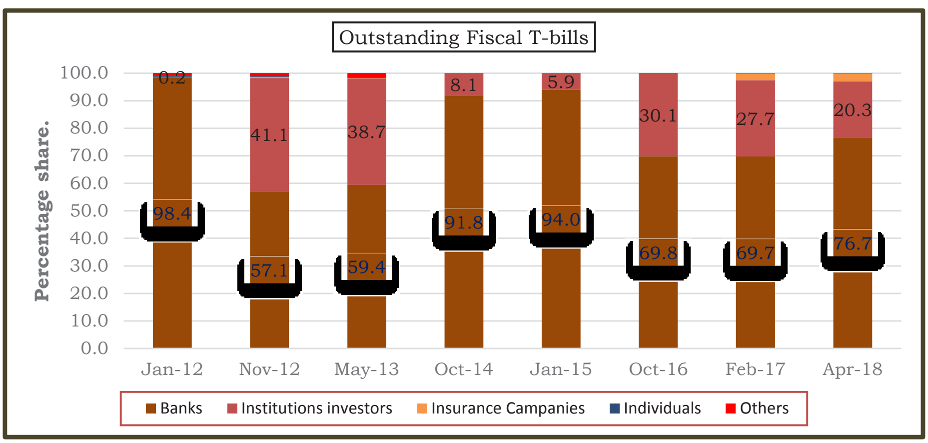
Source: Research department, BNR.

In accordance with provisions of the instruction No 05/98 of September 24th, 1998, BNR decided to intervene on the money market by issuing Treasury bills for period relatively long of 28; 91; 182; 364 days maturity. This mode of financing government spending was a result of financial reforms that aims at limiting the inflationary financing of the Government cash deficit by the Central Bank overdrafts. Central bank bills are also used for monetary policy purposes, to sterilize excess liquidity when Treasury bills and other liquidity mop up instruments fail to bring the reserve money to the targeted levels.

With the current market practice, bids are classified in 2 categories: competitive and non-competitive. Competitive bids must indicate the offered price (the interest rate), while the weighted average rate of the retained competitive bids are applied to non-competitive bids.

For the past few years, the share of the total T-bills holdings reduced from banks in favor of other participants, and this shows how the instrument is becoming more attractive for different categories of economic agents.

Figure 2: Share of outstanding Fiscal T-bills by category of investors (2012-2018)

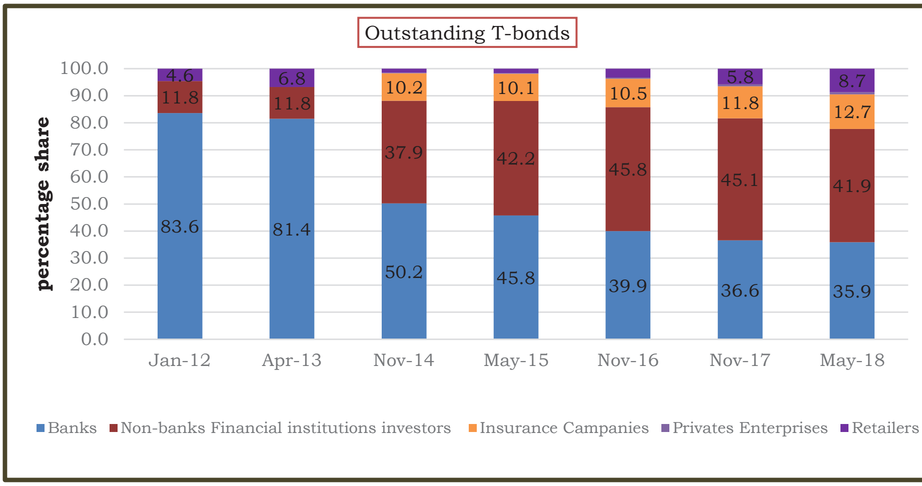


Source: Research department, BNR

The development of money market has progressively contributed to the development of capital market, market for long term securities and the control by BNR of the short term interest rates is expected to increase its capability of impacting the aggregate demand in the economy.

Capital market in Rwanda is providing saving opportunities to more economic actors, increasing the scope for BNR monetary policy. The share of institutional investors increased from 23.4 percent by December 2014 to 54.9 percent end June 2018, and the share of retail investors increased to 9.0 percent from 1.6 percent in the same period. On the other hand, the share of banks in government bonds declined from 50.1 percent end December 2014 to 36.1 percent end June 2018.

Figure 3: Share of outstanding T-bonds by Investors (2012-2018)



Source: Research department, BNR

2.2. Interbank market development

Inter-bank market is where the banks borrow and lend among themselves to meet the short-term credit and deposit needs of the economy. Efficiency of the interbank market is very vital for the effective conduct of monetary policy. It acts as the conduit for the transmission of monetary policy through the interest rate and credit channels. It is a channel for liquidity management in the banking system, and provides an effective price-discovery mechanism in the money market as a whole. Temporary imbalances may arise from time to time, but the market should restore equilibrium and close undesirable gap, without intervention of the central bank. Consequently, interbank rates can be used as effective guide for loans, savings, mortgages, futures, options and swaps. Wide deviations between interbank rates and retail market rates are therefore a sign of inefficiencies at the interbank market, which may compromise the role of the interbank market as a mechanism to restore equilibrium in the markets

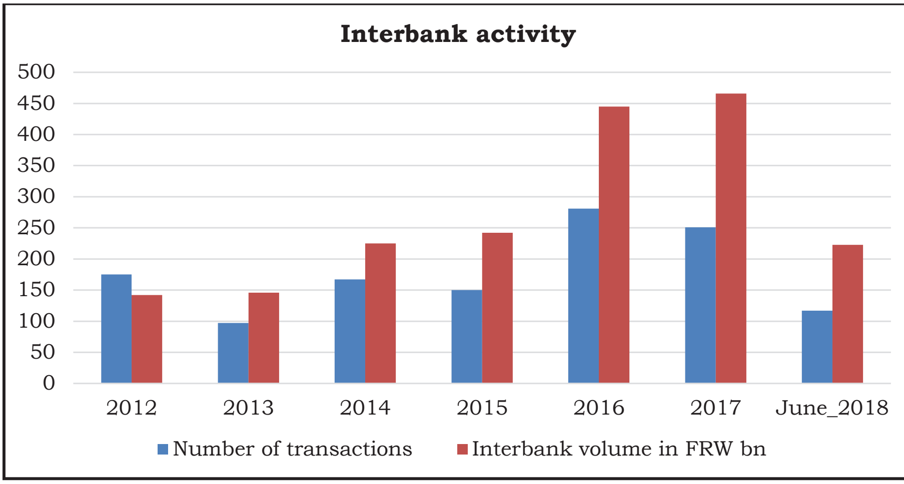
With the perspective of boosting interbank market activities and therefore enhance monetary policy transmission mechanism, the BNR established a Financial Markets Operations Committee (FMOC) to reduce the uncertainty in daily monetary policy operations, and distortions in money market interest rates. This is done by improving daily liquidity management and therefore lowering the excess liquidity in Rwandan banking system that has been significantly above the estimated optimal level (Kigabo and Gichondo, 2018), and guide BNR interventions on money market. Persistent excess liquidity contributed to reducing transactions in the interbank market and limited the BNR interest rate (KRR) to an opportunity cost for banks to hold excess liquidity rather than playing the role of cost of funds for commercial banks.

The FMOC meets every working day since mid-2016 and take decision on the amount to mop up in banking system through repo instrument. The proposals and decisions of the committee are based on the detailed analysis of current liquidity conditions prevailing the money market, daily liquidity forecasting, and information from market intelligence.

In addition, the true repo, which consists of enhancing the existing interbank market whereby banks are engage in safe and collateralized borrowing and lending activities, contributed to increase the trust of players on interbank market as all transactions are collateralized and ownership of security holders is fully transferred during the borrowing period. As result, transactions in interbank market have increased over time.

From the past six years, the value of transactions in interbank market nearly quadrupled, from FRW 175 billion in 2012 to FRW 466 billion at end of 2017. In the first half of 2018, the total interbank market transactions significantly increased to FRW 222 billion, higher than the average total transactions of the years 2012-2015. In addition, the number of players on interbank market increased from 9 banks in 2015 to 12 (out of 16) banks in 2017 and first eight months of 2018. This is a good development because liquidity providing or withdrawing operations by BNR is disseminated to 75% of commercial banks.

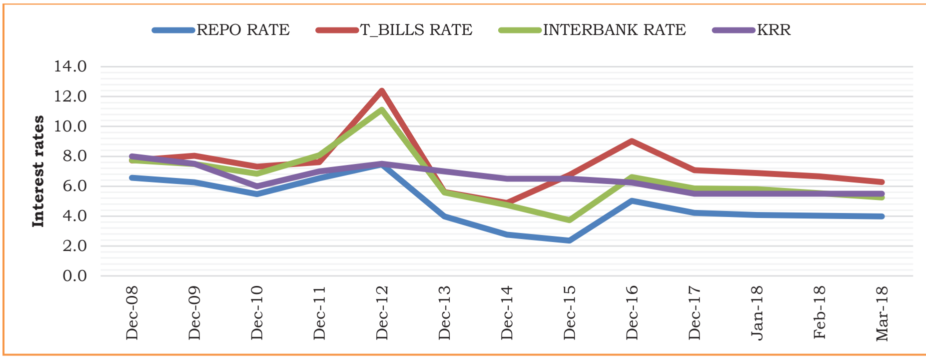
Figure 4: Inter-bank market developments



Source: Research Department, BNR.

These developments in the money market contributed to align money market rates with the key policy rate, improving the capability of BNR to influence the money market rates, which is key for the transmission mechanism of monetary policy. As indicated in the graph below, there is a clear co movement between repo rates, Treasury bill rates and interbank rates since end 2016 and all converging toward the KRR. The transmission mechanism from central bank rate (KRR) to money market rates paves the way to the adoption of price based monetary policy.

Figure 5: Money market rates show greater co-movement



Source: Research Department, BNR.

Besides, it is necessary to assess the degree to which volatility in interbank rate leads to volatility in financial instruments with longer maturities (e,g: T-bills). Modern central banks typically act to smooth interbank rates at or close to the policy rate aiming at influencing and stabilizing longer-term rates, important for overall level of prices and real economic activity. Likewise, the central bank's ability to reduce volatility of interbank rates should matter for monetary policy because, changes in the policy rate may not have the intended effect on funding costs for longer-term maturities, if accompanied by increased volatility of the overnight market interest rate, all else equal (Cohen,1999).

2.3. Modeling interbank rate volatility

To model the interbank rate volatility and its transmission onto volatility of higher maturity yields in Rwanda, we follow Ayuso *et al.* (1997) and Alper *et al.* (2016). More specifically, in this paper we use the E-GARCH specification, which allows for asymmetric positive and negative deviations of rates.

We specify the mean equation with the form of an AR(m) model as follows:

$$\Delta r_t = \alpha_0 + \alpha_1 (r-p)_{t-1} + \beta_1 \Delta r_{t-1} + \square_1 \Delta p_{t-1} + \varepsilon_t \quad (1)$$

Where r is the interbank rate, and p is the repo rates as a proxy for the policy rate. The lagged interbank-policy rate spread (with coefficient α_1) represents the error correction and allows for a long term-reversion process between the policy and interbank rate, ε_t is the error term.

The log-linear form is also estimated and has the additional advantage that there is no need to restrict the coefficients in the conditional variance specification to ensure a non-negative variance. Specifically, we estimate:

$$\underbrace{\log\left(\sigma_t^2\right)}_{\sigma_t^2>0} = \omega + \beta \log \sigma_{t-1}^2 + \alpha \left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \qquad (2)$$

The term ε_{t-1} comes from the mean equation, and is the deviation of the expected value of the interest rate conditional on all past information:

$\varepsilon_t \;=\; E_{t-1}[\Delta r_t] - \Delta r_t \;=\; \delta_t^2 z_t$ for some standardized random variable z.

After obtaining the estimated conditional variance of the interbank rate series, we then proceed to model the volatilities of the 4, 13, 26-, and 52-week T-bills rates. The process is identical to that of the interbank model, with two exceptions. First, the error correction term $(r-p)_{t-1}$ is not included in the mean equation. Secondly, we include the estimated conditional variance of interbank rate (in natural logarithm) into the log-linear form of the variance equation. The coefficient of this term would be interpreted as the proportion of interbank volatility transmitted to the longer-maturity rate (Ayuso *et al.*, 1997).

$\boldsymbol{\beta_1}$: The coefficient of autoregressive lagged interbank rates.

$\square_1$: The coefficient of current and possible lags of policy rate changes.

$\boldsymbol{\alpha_1}$: The coefficient of spread, defined as the interbank less the policy rate.

ω: The coefficient on the GARCH effect.

β: The coefficient that captures the effect of the conditional shock on the conditional variance to measure the persistence of the shock

α: The coefficient of the ARCH effect and captures the asymmetric effect.

ϒ: Coefficient of the natural logarithm of the conditional volatility of the relevant interbank rate. A positive and significant value implies volatility transmission from interbank rate to longer maturity instrument.

We find in all cases that an E-GARCH (1,1) specification was appropriate to estimate the conditional variance. We find leptokurtosis in residuals, and so opt to estimate the model with a student's t-distribution. All diagnostics tests point to a well specified and stable model; the correlograms (residuals in level and squared) suggest that all autoregressive effects have been captured.

Second column of Table 1 presents the mean-variance model for Rwanda's interbank interest rate estimated for January 2008-June 2018. In the mean model, a change in the policy rate has a statistical significant impact on Rwanda's interbank rate, though small. The impact of a percent change in policy rate will lead to 0.35% change in interbank rate. Moreover, the difference between the policy rate and interbank rates narrows gradually, at the rate of 0.18 percent (the error correction model).

The variance equation for interbank rate model has significant ARCH and GARCH effects, indicating the autocorrelation and persistence in conditional volatility, with variance coefficient of 0.57. The same equation shows the presence of asymmetrical effect; meaning that positive shocks (lagged) shocks generate higher volatility in the money market. The findings have also shown the persistence of shocks to the variance.

Table 1: Estimation results

Mean equation	Interbank rate	4weeks T-bills	13weeks T-bills	26weeks T-bills	52 weeks T-bills
α_0	0.63***	0.40**	0.15	-0.06	-0.77***
β_1	-0.05***	-0.06***	0.00	0.05***	0.10***
Υ_1	0.35**	0.61***	0.05***	0.24**	0.10***
α_1	-0.18***	-	-	-	-
Variance equation					
ω	-0.85***	-1.1***	-1.20***	-0.08	-2.13***
β	0.57***	1.25***	1.03**	-0.10	2.83***
α	0.28***	0.48**	-0.005	-0.58***	-1.34***
Υ	0.76***	0.81***	0.71***	0.24**	0.82***

(***, **,* represents the level of significance at 1%, 5%, and 10% level of significance respectively).

The symbols in the tables represent:

α_0: Constant

Our findings also show evidence of volatility transmission from the interbank rate to Treasury bill rates, but the transmission reduces as maturity becomes longer.

Our findings are similar to the findings of Alper *et al* (2016) that suggest that volatility transmission, and its persistence and autocorrelation, are more likely in countries in transition to a more forward-looking monetary policy framework. One hypothesis could be that once expectations fully incorporate the implicit "reaction function" of central banks into their decisions, markets will not react immediately to episodes of volatility spikes in money markets at all maturities.

Columns 3-6 in Table 1 presents mean-variance model estimates for Rwanda. Autoregressive coefficients are significant and range from -0.06 to 0.1.

We also find the presence of ARCH and GARCH effects at all maturities. The ARCH term is the contribution from the absolute residuals in the mean equation; and its significance means that the observed volatility of the last period provides additional information when the last period forecasted volatility is taken into account. The GARCH term corresponds to the previous period's estimated conditional variance; and its significance implies volatility clustering.

III. MONETARY TRANSMISSION MECHANISM IN RWANDA

In this section, we assess the transmission mechanism of monetary policy in Rwanda as results of recent financial reforms and financial innovation as well as improvement in monetary policy management by the National Bank of Rwanda. For that purpose, we first use single equations to analyze specifically the response of money market rates (interbank rates and Treasury bill rates) to changes in repo rates used as proxy of central bank rate. Finally, we estimate impulse response functions (IRFs) based on VARs with a small number of macro variables, as in many studies on monetary transmission mechanism. In several studies, including ours recently published, identification of structural innovations is done using Choleski decomposition.

In this study, we adopt a non-recursive structural VAR to take into consideration some specificities of the Rwandan economy, particularly the estimated money demand function.

3.1. Single equation approach

The first step of the transmission mechanism relates changes in policy rates to changes in money market rates. One of simple ways of assessing that link is to calculate correlations between those changes by estimating the following equation (Mishra *et al.*, 2010)

$$y_t = \alpha y_{t-1} + \beta y_{t-2} + \gamma x_t + \delta x_{t-1} + \eta x_{t-2} + \varepsilon_t \quad (3)$$

Where y is change in the money market rate and x the change in the discount rate. The short term effect is the average estimated γ; the long-term effect reported is calculated as following:

$$LTeffect = \frac{\hat{\gamma} + \hat{\delta} + \hat{\eta}}{1 - \hat{\alpha} - \hat{\beta}} \quad (4)$$

We use the same equation to analyze the transmission mechanism from money market rates to market rates (deposit and lending rates), where y is change in the deposit rates and lending rates and x the change in the money market rates. The transmission from the policy interest rate to the lending and deposit rates is part of the broader issue of the effectiveness of interest rate policy in controlling inflation by affecting aggregate demand.

3.2. VAR model

We estimate the following VAR model

$$H(L)Y_t = K(L)X_t + \varepsilon_t \quad ; \quad VAR(\varepsilon_t) = \Lambda \quad (5)$$

The corresponding reduced form is

$$Y_t = A(L)Y_{t-1} + B(L)Z_t + \mu_t \quad (6)$$

Where Y_t is a vector of endogenous variables and Z_t a vector of exogenous variables. Y_t consists of GDP in constant prices (y), Consumer Price Index, CPI (p), nominal effective exchange rate (e), monetary aggregates and short term interest rates such as repo rates and T-bills rate (i).

A(L) corresponds to matrices of coefficients to be estimated, with lag lengths determined by standard information criteria. The vector Z_t consists of exogenous variables used to control for changes in global economy.

We adopt the following order of endogenous variables:

$$Y'_t = [y_t, p_t, m_t, i_t, e_t] \quad (7)$$

3.3 Empirical findings

Table 2 reports statistics on the relationship between repo rates (as a proxy for policy rates) and money market rates in Rwanda. Columns 3 and 4 report the short and long-term correlations between the policy rate and money market rates.

The first part of the table indicates a statistically significant correlation between repo rates and interbank rates only during the recent period, between January 2016 and June 2018[3]. The second part of table analyses the link between money market rates (interbank rates and Treasury bill rates by different maturities) and deposit rates by different maturities. For the entire sample (January 2004 to June 2018), significant correlations are reported between weighted treasury bill rates and weighted deposit rates as well as deposit rates for all maturities except one year deposit rates. Thirteen week Treasury bill rates are correlated with all deposit rates for a sample starting in January 2008. However, all correlations, short term and long term ranging from 0.01 to 0.06 and from 0.03 to 0.12 respectively are very low compared to the average correlations in Low Income Countries, which are 0.29 and 0.4 respectively (Mishra *et al.*, 2010).

In line with the observation made on the figure 1, money market rates have been converging toward KRR since 2015. This contributed to improve the link between interbank rates and deposit rates, particularly one-month deposit rates with short term and long-term correlations of 0.22 and 0.24 respectively

[3] Estimated correlations between repo rates and Treasury bill rates using data from 2004 are not significant. Those correlations are not reported here. In the table, we only report significant correlations.

and very closed to correlations in LIC. In addition, R-squared increased significantly between 0.38 and 0.46 depending on deposit rates.

Table 2: From policy rates to market rates

	Y	Short- term effect	Long term effect	R-squared	Period
Repo rates	Interbank rate	0.04	0.03	0.21	2016:1-2018:6
Treasury bill rates	Deposit rate	0.04	0.08	0.27	2004:1-2018:6
	Three months deposit rates	0.1	0.19	0.28	
	Six months deposit rates	0.05	0.08	0.16	
	Twelve month deposit rates	0.01	0.05	0.17	
Thirteen week Treasury bill rates	Deposit rates	0.03	0.07	0.19	2008:1-2018:6
	One month deposit rates	0.04	0.10		
	Three months deposit rates	0.06	0.12	0.22	
	Six months deposit rates	0.05	0.05	0.12	
	Twelve month deposit rates	0.02	0.05	0.13	
Interbank rates	Deposit rate	0.03	0.02	0.46	2015:1-2018:6
	One month deposit rates	0.22	0.24	0.38	
	Twelve month deposit rates	0.20	0.16	0.41	

Source: Authors' estimation

In Table 3, the first column contains market rates while the second contains money market rates. Correlations are calculated for recent data, from January 2015 or January 2010. We have maintained sub samples where correlations are significant. The general conclusion is that the link between money market rates and deposit rates has significantly improved in recent years as results of improved liquidity forecasting and management as well as development in financial markets, both money market and capital market. Some correlations are bigger than the average in LICs. However, the link between money market rates and lending rates still very weak. In addition, even though the link between deposit rates and short-term lending rates is statistically significant, the correlation coefficients are very low (0.11 and 0.04 respectively for deposit rates and 12 month deposits rates).

Table 3: Correlation between market and money market rates

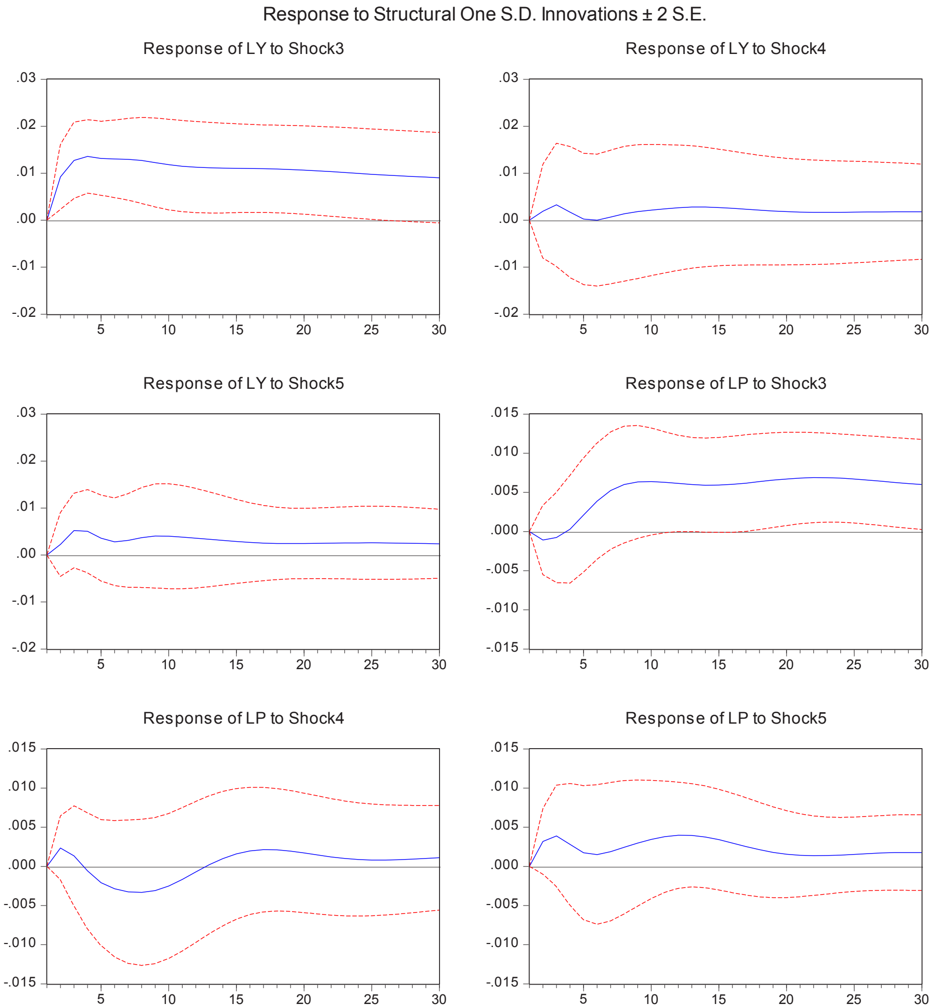
Y	x	Short-term effect	Long term effect	R-squared	Period
Deposit rates	Treasury bill rates	0.03	0.2	0.35	2015:1-2018:6
	26 week Treasury bill rates	0.03	0.25	0.38	2010:1-2018:6
	52 week Treasury bill rates	0.08	0.13	0.34	
Three month deposit rates	13 week treasury bill rates	0.4	0.44	0.42	
	26 week treasury bill rates	0.4	0.49	0.46	
	52 week treasury bill rates	0.15	0.43	0.42	2010:1-2018:6
Short term lending rates	Deposit rate	0.1	0.11	0.47	
	Twelve month deposit rates	0.0003	0.04	0.20	2015:1-2018:6

Source: Authors' estimation

The main conclusion from this analysis is that the link between money market rates and deposit rates improved in recent years though correlation coefficients still low in general. This is good development in interest rate monetary transmission mechanism. However, weak link between money market rates and lending rates is an indication of BNR challenges to impact the aggregate demand in the Rwandan economy through the costs of financial resources. The possible channel remaining is the influence of the economy through the amount of the money and not its value. We assess the channel by using a VAR model and as mentioned, the particularity of this study is to use non-recursive scheme to identify structural innovations. Particularly we took into consideration, the estimated money demand function in Rwanda.

Impulse response functions indicate that both GDP and prices react to change in M3. A recent study by Kigabo (2018) using Choleski decomposition and credit to the private sector instead of M3 has confirmed that BNR actions influence GDP and prices with lag, by influencing the volume of credit rather than its price.

Figure 6: Estimated impulse response functions



CONCLUSION

The objective of this study was to analyze progress achieved by BNR in developing money market and identify possible channels for monetary transmission mechanism ahead of adopting price based monetary policy.

In the effort to influence the underlying demand and supply conditions for its money, BNR has progressively put in place different requirements to enhance the role of price signals in the economy, including the development of money market in Rwanda.

The development of government securities market contributed to make a clear separation between money creation and government funding needs, which contributed to well manage the BNR balance sheet. However, the government securities market is dominated by commercial banks with no activity on the secondary market, which limit BNR influence on other possible market participants.

Good progress is achieved in the development of interbank market in recent years. However, the market remain shallow and this limits the effectiveness of money market operations and contributed to weaken the interest rate pass through which is the first block of interest rate channel. More effort is needed to attract more players on the market because money market operations are effective when the central bank actions are disseminated to all financial institutions.

The analysis has concluded to certain volatility transmission from the interbank rate to higher maturities and its persistence, though the transmission reduces as maturity becomes longer, as is the case in countries transitioning to a more forward-looking monetary policy framework. This suggests that the mitigation of volatility transmission from interbank rate to long-term maturity yields deserve consideration for policy decision. The emphasis should be made on a strong commitment to the interbank rate as an operational target, by creating a narrower corridor that would force a faster rate of convergence in interbank rates, reduces the persistence in volatility, and mitigate absolute volatility along the yield curve. This effort should be supported by other policies such as enhancing coordination between fiscal and monetary operations and improving the market infrastructure. Significant volatility transmission in transition economies suggests that central bank policies can contain volatility rapidly by significantly smoothing out the interbank interest rate around the policy rate thereby making monetary policy more effective.

In addition, more capacity building in liquidity forecasting will be crucial. Indeed, effective capacity to forecast liquidity developments in the system (that is, to forecast changes in the central bank's balance sheet) will allow the central bank to make informed decisions on the timing and size of its discretionary monetary operations. In turn, those operations will contribute to steering liquidity in the system to its optimal level, and create conditions for a smooth functioning of the market. Therefore, less concerned about the interest rate volatility that may arise due to forecasting errors, the BNR will be more disposed to set an interest corridor (spread between deposit standing facility and lending standing facility) to further support interbank market development and ensure that the structure of its policy rates is conducive to interbank trading.

REFERENCES

Ayuso, J., A. G. Haldane, and F. Restoy. 1997. "Volatility Transmission along the Money Market Yield Curve," *Weltwirtschaftliches Archiv*, Vol. 133(1): 56-75.

Kigabo, R., and J.P. Mutuyimana 2016. "Financial innovations and monetary policy in Rwanda". *BNR Economic Review*, Vol.9:1-29..

Emre A., R. Armando Morales, and F. Yang. 2016. "Monetary Policy Implementation and Volatility Transmission along the Yield Curve: The Case of Kenya". IMF Working Paper WP/16/120.

De Fiore F. 1998., "The Transmission of Monetary Policy in Israel". IMF Working Paper No WP/98/114.

Mishkin, F.S. 2002. *The Economics of Money, Banking, and Financial institutions*, (11th Edition), Pearson series. Toronto, Canada.

Cohen, B., 1999, "Monetary Policy Procedures and Volatility Transmission along the Yield Curve," CGFS Papers chapters, in: Bank for International Settlements (ed.), *Market Liquidity: Research Findings and Selected Policy Implications*, vVol. 11:1-22.

Jacob O., *et al.* 2014. "Segmentation and efficiency of the interbank market and their implication for the conduct of monetary policy,", African Development Bank Group Working paper No 202.

Kigabo, T., 2018. "Monetary transmission mechanism in Rwanda", in: *Rwanda Handbook of Economic and Social Policy*, Heshmati A. (Ed), Jönköping International Business School, PP.497-524..

Kigabo, T. and A. Gichondo. 2018. "Excess liquidity and monetary policy in Rwanda", in: *Rwanda Handbook of Economic and Social Policy*, Heshmati A. (Ed), Jönköping International Business School, PP.525-542..

Mishra, P. A. Spilimbergo and P. Montiel. 2010. "Monetary transmission in low income countries," Center for Development Economics 2010-06, Williams College, Boston, MA.

Saxegaard, M. 2006. "Excess Liquidity and the Effectiveness of Monetary Policy: Evidence from Sub-Saharan Africa," IMF Working Paper, WP/06/115.

Annex 1: Money demand in Rwanda and its stability

Table 1: Johansen cointegration test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.514498	70.95069	54.07904	0.0008
At most 1 *	0.480465	44.21553	35.19275	0.0041
At most 2	0.272688	19.98712	20.26184	0.0545
At most 3	0.198918	8.206308	9.164546	0.0758

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

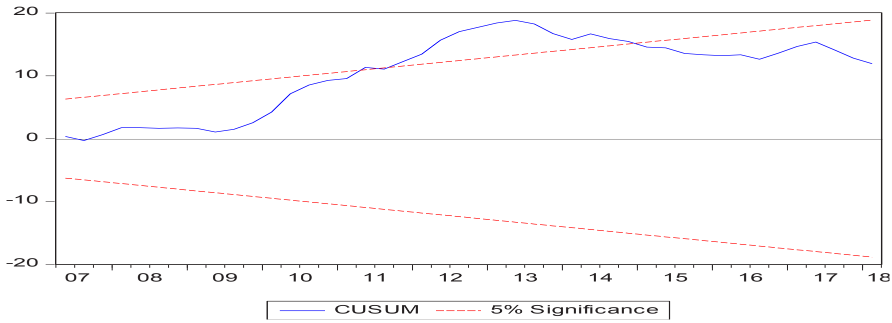
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.514498	26.73516	28.58808	0.0846
At most 1 *	0.480465	24.22841	22.29962	0.0266
At most 2	0.272688	11.78081	15.89210	0.1990
At most 3	0.198918	8.206308	9.164546	0.0758

Table 2: Cointegrating equation

Normalized cointegrating coefficients (standard error in parentheses)

LOG(M3)-LOG(P)	LOG(Y)	LOG(NEEP)	TB-DR	C
1.000000	-1.951121	0.629702	0.015165	8.708252
	(0.10550)	(0.31838)	(0.00572)	(0.85122)

Graph 1: Stability of money demand: CUSUM test



OPTIMAL INFLATION FOR ECONOMIC GROWTH IN RWANDA

Ananias GICHONDO[4], Mathias KARANGWA[5], Ndahiriwe KASAI[6],

Pascal MUNYANKINDI[7]

[4] Ananias Gichondo is a Principal Economist in the Monetary Policy Department, National Bank of Rwanda.

[5] Mathias Karangwa is a Principal Economist in the Research Department, National Bank of Rwanda.

[6] Prof Ndahiriwe Kasai is the Director of Monetary Policy Department, National Bank of Rwanda.

[7] Pascal Munyankindi is a Principal Economist in the Monetary Policy Department, National Bank of Rwanda.

ABSTRACT

In addition to the primary objective of keeping inflation low and stable, the National Bank of Rwanda also has a mandate of supporting the Government's macroeconomic policies aimed at promoting economic growth. Rwanda has a long-term objective of attaining high-income status by 2050 and this requires a GDP growth rate of 9.0% and above per annum. The Central Bank's monetary policy can be either expansionary or contractionary and this stance depends on whether inflation has gone beyond a desired level or not. If the inflation objective is not realistic, it can have undesired implications on economic growth. The relationship between long-run economic growth and inflation has been found to be either positive, negative or neutral. This paper estimates the threshold level of inflation to help guide monetary authorities in their endeavor to set an inflation objective as the BNR switches to a price based monetary policy framework. Results show that the threshold inflation level for Rwanda is 5.9%, which is below the EAC inflation ceiling of 8.0% and within the BNR's band of 5±3%. The estimated threshold inflation level is consistent with 9.0% growth in real GDP.

Key words: Optimal inflation rate, monetary policy, Rwanda**.**

JEL Classification: E31, E52, E58, O40

I. INTRODUCTION

Like most central banks around the world, the primary objective of monetary policy in Rwanda is to keep inflation low and stable and therefore support the Government's macroeconomic policies aimed at promoting economic growth.

Literature is awash with studies exploring the link between inflation and economic growth. These studies explore whether this relationship is either linear or non-linear; a linear relationship implies that inflation and economic growth are consistently positively related. Conversely, a non-linear relationship implies that inflation and economic growth are positively related up to a certain "threshold" inflation level, beyond which economic growth starts to decline.

Theoretically, there has been debate on the long-run relationship between inflation and economic growth. The Mundell-Tobin hypothesis (Mundell, 1965; Tobin, 1965) assumes that since money and capital are substitutes, an increase in inflation lowers the purchasing power of real money balances, inducing economic agents to hold less money and more of real assets and resulting into increased capital accumulation and economic growth. Considering money to be complementary to capital, the Stockman effect (Stockman, 1981) asserts that inflation and economic growth are negatively related in the long run. In disagreement with the above, Sidrauski (1967) showed that money is neutral and super-neutral in an optimal control framework with money in the utility function. Therefore, a rise in inflation has no effect on output growth.

It has been argued that situations characterized by either too high inflation or too low inflation are sub-optimal. For example, too high inflation disturbs the efficient allocation of resources, cripples the external sector competitiveness and lowers domestic financial savings among others, thereby negatively affecting economic growth in the long run. Therefore, the view that central banks need to keep inflation low and stable has gained acceptance across the world in modern times. However, the empirical question has been the determination of an optimal inflation threshold beyond which inflation starts to adversely affect economic growth (Busetti *et al.*, 2006). Important to note is the fact that optimal inflation for economic growth is country-specific and therefore varies across countries depending on differences in economic conditions (Morar, 2011). Therefore, a country-level study addressing this topic is worth undertaking.

For the case of Rwanda, the first paper on the topic was conducted by Musoni (2015). Using annual data from 1968 to 2010, he estimated the inflation threshold at 12.7%. The annual average real GDP growth for the whole sample period was 5.4%, while the average inflation rate was 9.5%. While the study provided useful insights on the optimal level of inflation for economic growth in Rwanda, it suffers from some weaknesses, such as the fact that most of the historical data that go as far back as 1968 are affected by noise emanating from change in measurement methods, structural changes in the economy, among others. Thus, we update the results by Musoni (2015) using the most recent data.

To continue supporting the Government to maintain strong and sustainable GDP growth and therefore push the country to a middle-income status without contradicting its primary mandate of price stability, the National Bank of Rwanda is planning to shift from a monetary targeting regime to a price based monetary policy framework. Thus, before setting inflation objectives, there is a need for monetary authorities to determine the optimal level of inflation, which is in line with sustainable national macroeconomic stability as well as the broad development policies and strategies for moving the economy forward in the coming years. In view of the above, this paper uses quarterly data spanning from 2007 to 2017 to estimate the level beyond which headline inflation stars to impede economic growth in Rwanda.

The rest of the paper is organized as follows: section two provides a brief review of the literature, followed by explanation of the methodology in section three. The fourth section dwells on analyzing Rwandan data, specifically focusing on inflation and GDP growth as well as on the hypothetical relationship between them. A more rigorous assessment of the relationship between inflation and GDP growth is presented in section five, where linear and quadratic models linking the two variables are estimated to come up with a threshold level of inflation. Building on the above, section six gives the main conclusions and policy recommendations of the study.

II. LITERATURE REVIEW

Theoretically, the inflation-growth nexus was first discussed by Keynes in his Aggregate Demand (AD)-Aggregate Supply (AS) theory. Keynes does not necessarily attribute high economic growth to inflation but rather argues that since the AS curve is upward sloping in the short-run, an outward shift of the AD curve increases both output and inflation and this is a result of the time inconsistent problem. In simple terms, any improvement in output is accompanied by some benign increase in inflation and this is purely a short-run phenomenon given that it is unsustainable in the longer-term and turns negative with a higher inflation rate as the supply curve becomes vertical. In the long-run, demand side policy no longer increases the level of output but only the level of price (Dornbusch, *et al.*, 1996).

Basing on the above, Neo-Keynesians estimated the potential level of output and argued that inflation increases (decreases) when the gap between actual and potential output, also called the output gap, increases (decreases). The output gap therefore is used as a measure of demand-side inflationary pressures in the economy. When the output gap is positive and unemployment is below the natural rate, inflation accelerates, causing an outward shift of the Phillips curve and indicating higher inflation with higher unemployment (Gordon, 1997).

According to the endogenous growth models, return on capital depends on the level of economic growth. The latter is influenced by factors such as economies of scale, increasing returns or induced technological change. Thus, high inflation makes economic agents to substitute goods for leisure, lowering the return on human capital and thereby reducing the return on all capital and the economic growth. Therefore, inflation and economic growth are inversely related (Gillman *et al.*, 2001).

According to monetarists, there is inflation inertia in the economy when the growth rate of money persistently exceeds the growth rate of the economy, forcing wages to adjust as workers anticipate future increments in the interest rates. Therefore, monetarists assume a positive relationship between inflation and growth and thus disagree with the Phillips curve that postulates a negative relationship, whereby there exists a sacrifice ratio, showing the amount of output that has to be foregone in order to bring inflation back to the target.

The neo-classical economists, such as Tobin (1965) assume that inflation entices economic agents to invest more into interest-earning assets rather than holding real money balances whose value erodes with an increase in inflation. Increased investment into these assets promotes capital accumulation and results into higher economic growth, hence a positive relationship between inflation and economic growth.

Later, it was proved that the relationship between long-run economic growth and inflation is either positive (Mundell, 1965; Tobin, 1965) or negative (Stockman, 1981) or neutral (Sidrauski, 1967). These relationships are well explained in the so-called Mundell-Tobin effect, Stockman effect and Sidrauski effect. Subsequent empirical literature, such as Hansen (1999), Gonzalo and Pitarakis (2002), all summarized in Drukker *et al.* (2005), take note of the non-linear relationship between inflation and economic growth, with inflation that is beyond a certain threshold thought to have detrimental effects on economic growth.

The non-linearity of the effect of inflation on economic growth implies that low inflation is conducive for growth while high inflation is detrimental for growth. Therefore, there exists a turning point, beyond which a further increase in inflation becomes harmful to economic growth. This turning point or threshold is what has been called the optimal level of inflation (Nkume and Ngalawa, 2014).

An optimal inflation threshold is the level of inflation at which economic growth is maximized and it varies across countries. Therefore, central banks that simply target low inflation with the assumption that it improves economic performance, fail to maximize economic growth because they do not target their economy's specific threshold inflation rate (Morar, 2011).

A number of studies explored the link between inflation and GDP growth by estimating the turning point or threshold level of inflation. According to Khan and Senhadji (2001), threshold inflation varies between 1.0% – 3.0% for developed countries, 11.0% – 12.0% for developing countries and 9.0% for all countries, respectively. For Sub-Saharan Africa, Ndoricimpa (2017) estimated the inflation threshold at 9.0% for low-income countries, 6.5% for middle-income countries and 6.7% for all countries taken together.

In Egypt, Hosny *et al.* (2014) used data for the 1981-2009 period to estimate the Hansen threshold regression. Their model included GDP growth, Inflation, the square of inflation, gross fixed capital formation, credit to the private sector, trade, openness, government consumption expenditure, Nominal exchange rate and population growth rate. They concluded that the threshold level of inflation in Egypt is 12.0%.

Fabayo and Ajilore (2006) used data for the 1970–2003 period to estimate a threshold regression model based on threshold regression model by Khan and Senhadji (2001), including lagged inflation and investment. Their findings show that the optimal level of inflation for growth in Nigeria stood at 6.0%.

Yabu and Kessy (2015) analyzed the impact of inflation on growth in three EAC countries and found that the threshold level for the selected states is 8.5%. Estimating the threshold level for individual countries, the study indicates that the optimal level of inflation for Kenya is 6.8%, 8.8% for Tanzania and 8.4% for Uganda.

Concerning Rwanda, Musoni (2015) uses annual data from 1968 to 2010 to estimate an inflation threshold at 12.7%. The annual average real GDP growth for the whole sample period was 5.4%, while the average inflation rate was 9.5%. One drawback of this study is the fact that it uses historical data that go as far back as 1968 subject to noise emanating from change in measurement methods, structural changes in the economy, among others.

III. METHODOLOGY

To find out the optimal inflation threshold level, most of the recent studies referred to the cross-country estimation of Khan and Senhadji (2000), sometimes modified by adding control variables like terms of trade, population growth and investment. This study followed the threshold model with dummy methods developed by Nazir, Saeed and Mahammad (2017) for the case of Pakistan. The model is also a modified Khan and Senhadji's estimation, which is based on two variables, namely economic growth and inflation.

$$\text{GDP}_t = \beta_0 + \beta_1 Inf_t + \beta_2 D_t (Inf_t - K) + \varepsilon_t \quad (1)$$

Where GDP is the GDP growth rate, Inf is the annual CPI headline inflation rate, K is the threshold level of inflation, D is the dummy variable indicating the presence of an inflation rate that is smaller or greater than the threshold level, K, and εt is the error term.

$$D_t = \begin{cases} 1 : Inf_t > K \\ 0 : Inf_t \leq K \end{cases}$$

The relationship between economic growth and inflation is given by $\beta 1$ for low inflation and $\beta 1 + \beta 2$ for high inflation. The coefficients $\beta 1$ and $\beta 2$ are added to find their effect on growth when inflation is above K and the value of K is chosen arbitrarily over a range of values suspected to yield an optimal level of inflation. From a sequence of regressions estimated using different levels of K, the optimal inflation threshold is the one that minimizes the residual sum of square (RSS) and maximizes the R-squared (R2). To ensure the non-linearity of the model, equation (1) was improved by augmenting the level of inflation to get the following quadratic function:

$$Gdp_t = \alpha_0 + \alpha_1 Inf_t + \alpha_2 Inf_t^2 + \varepsilon_t \quad (2)$$

Using the quadratic equation, the relationship between Economic growth and inflation is given by α_1 and α_2 for low inflation and high inflation, respectively.

Given that equation (2) is a differentiable function of GDP growth, we can find the value of inflation that maximizes the function by applying a simple optimization rule.

IV. DATA ANALYSIS

In this study we estimated the optimal level of inflation for GDP growth based on quarterly data from 2007Q1 to 2017Q4 and as aforementioned, we followed the threshold model with dummy methods built from the bivariate relationship between GDP growth and inflation.

However, most economic time series are non-stationary and this can yield fallacious regressions. Thus, before any estimation and descriptive statistics analysis it is important to test variables for stationarity.

4.1. Stationarity test

The stationarity properties of variables were examined using Augmented Dickey-Fuller (ADF) tests and as shown in the table below, the two variables are stationary in level. This suggests that although inflation and GDP growth may regularly deviate from their means, there is a tendency for them to stabilize to their average levels respectively.

Table 1: Stationarity tests

Method			Statistic	Prob.**
ADF - Fisher Chi-square			16.4499	0.0025
ADF - Choi Z-stat			-2.99869	0.0014
Series	Prob.	Lag	Max Lag	Obs
GDP	0.0335	1	1	42
INF	0.0080	1	1	42

4.2. Preliminary data analysis

The causality as well as the correlation between inflation and GDP growth were checked and it was found that Granger causality runs both-ways (see table 2) and that there is a positive correlation, around 31 percent, between the two variables (see table 3).

Table 2: Causality test between variables

Null Hypothesis:	Obs	F-Statistic	Prob.
INF does not Granger Cause GDP	36	2.36784	0.0588
GDP does not Granger Cause INF		4.56161	0.0031

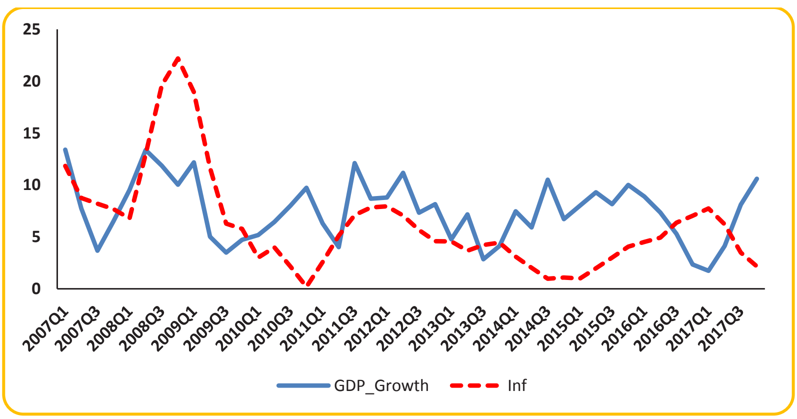
By two-way causal relationship, inflation Granger causes GDP growth and GDP growth Granger causes inflation. Notably, as these variables were found to be stationary in levels, one can be assured of meaningful results. Indeed, inflation can help to predict GDP growth and vice-versa. This confirms that there is a feedback effect from inflation to GDP growth and therefore, inflation can be regressed on GDP growth without fear of having spurious or misleading results.

Table 3: Correlation between inflation and GDP growth

	GDP	INF
GDP	1	0.311
INF	0.311	1

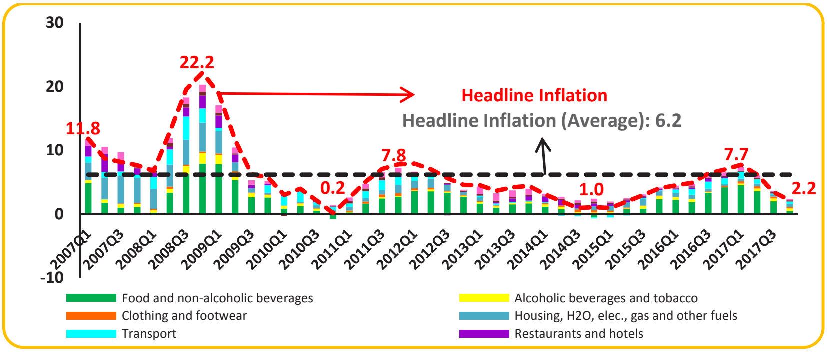
Figure 1 below which presents a visual analysis of the relationship between inflation and GDP growth demonstrates a co-movement between the two variables, though for some periods there is a lagged effect.

Figure 1: Real GDP growth and inflation from 2007 to 2017



This positive relationship between inflation and economic growth is in line with the general consensus from the literature that moderate inflation supports economic growth (Mubarik, 2005). Since 2007Q1, Rwanda recorded a moderate inflation, with the only outlier in 2008 due to the effect of the increase in international commodity prices. As shown in figure 2 below, inflation rose from 6.8% in 2008Q1 to 22.2% in 2008Q4 before dropping to 0.2% in 2010Q4 and continued moving around 4.4% on average during the remaining period, against 6.2% on average registered between 2007 and 2017.

Figure 2: Inflation developments in Rwanda



4.3. Relationship between inflation and GDP growth in Rwanda

The results from a simple OLS bivariate regression model indicate a statistically significant positive relationship between inflation and GDP growth.

Table 4: GDP growth and Inflation rate model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INF	0.192472	0.090613	2.124113	0.0396
C	6.317941	0.710987	8.886156	0.0000

This result is in line with the above descriptive statistics, especially the correlation test between inflation and GDP growth.

V. ESTIMATION OF THE THRESHOLD INFLATION

5.1. Threshold inflation by dummy method

The first step to estimate a threshold level is to determine a range of values suspected to yield an optimal level. For the purpose of macroeconomic convergence, the EAC partner States adopted a ceiling for headline inflation of 8.0%, which became, for each country, an operational definition of price stability. We also set the floor at 2.0%, similar to the inflation target in most advanced economies, given the fact that Rwanda aims at attaining middle-income status in the long run.

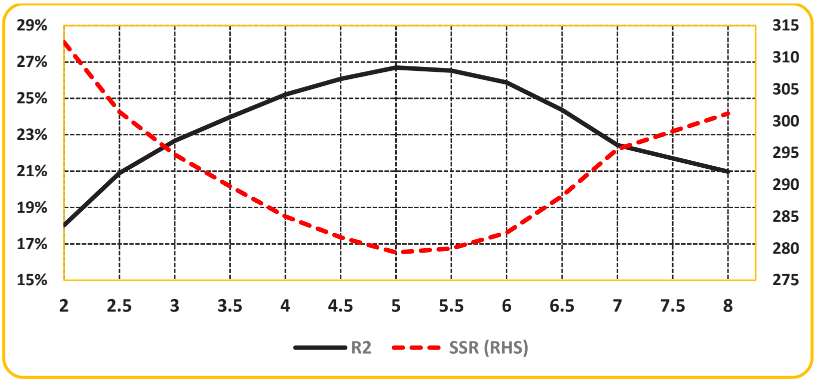
Therefore, we choose a range between 2% and 8%. We proceed to estimate, using the threshold dummy approach, a sequence of regressions of GPD growth on inflation and found the following results for the case of Rwanda.

Table 5: Estimation of inflation threshold model at $K \in [2,8]$

Variable		Coefficient	SD	T-stat	P-value	R^2	SSR
Inf	β_1	-2.265845	1.207834	-1.875958	0.0678	0.180263	312.3962
K2*(Inf – 2)	β_2	2.525921	1.237797	2.040659	0.0478		
Inf	β_1	-1.879833	0.864411	-2.174698	0.0355	0.208992	301.4481
K2.5*(Inf – 2.5)	β_2	2.169405	0.900441	2.409269	0.0206		
Inf	β_1	-1.487556	0.646501	-2.300935	0.0266	0.226619	294.7303
K3*(Inf – 3)	β_2	1.797684	0.685789	2.621337	0.0122		
Inf	β_1	-1.211239	0.512983	-2.361168	0.0231	0.239697	289.7466
K3.5*(Inf – 3.5)	β_2	1.544226	0.556688	2.773951	0.0083		
Inf	β_1	-1.001149	0.417863	-2.395879	0.0212	0.252044	285.0413
K4*(Inf – 4)	β_2	1.354853	0.464748	2.915242	0.0057		
Inf	β_1	-0.840955	0.352924	-2.382821	0.0219	0.260669	281.7543
K4.5*(Inf – 4.5)	β_2	1.216243	0.403712	3.012654	0.0044		
Inf	β_1	**-0.726237**	**0.309245**	**-2.348419**	**0.0238**	**0.266938**	**279.3652**
K5*(Inf – 5)	β_2	**1.127649**	**0.365774**	**3.082911**	**0.0037**		
Inf	β_1	-0.611050	0.274917	-2.222675	0.0318	0.265321	279.9814
K5.5*(Inf – 5.5)	β_2	1.032235	0.336800	3.064829	0.0038		
Inf	β_1	-0.501037	0.246253	-2.034644	0.0484	0.258806	282.4642
K6*(Inf – 6)	β_2	0.934931	0.312509	2.991695	0.0047		
Inf	β_1	-0.396528	0.225129	-1.761334	0.0856	0.243660	288.2364
K6.5*(Inf – 6.5)	β_2	0.835599	0.296357	2.819564	0.0074		
Inf	β_1	-0.303006	0.209088	-1.449179	0.1549	0.224286	295.6195
K7*(Inf – 7)	β_2	0.741554	0.285903	2.593726	0.0131		
Inf	β_1	-0.252608	0.197009	-1.282215	0.2070	0.217026	298.3862
K7.5*(Inf – 7.5)	β_2	0.703497	0.280617	2.506965	0.0162		
Inf	β_1	-0.212569	0.188216	-1.129387	0.2653	0.209689	301.1822
K8*(Inf – 8)	β_2	0.676509	0.279800	2.417830	0.0201		

Based on the results reported in the above table obtained from regressions and the graph below, the threshold level of inflation, which minimizes the RSS and maximizes R2 is 5%.

Figure 3: Graph of Residual Sum Squares (RSS) and R-Squared (R2)



At the maximum level, we expected that if inflation increases beyond 5%, GDP growth decelerates. However, we found that instead of decreasing, GDP rises by 0.4% for each 1% increase in inflation. Therefore, we cannot conclude that at 5% of inflation we no longer have room to improve the performance of the economy.

This result is not surprising as long as the estimated model is linear in nature. To overcome that limitation, we improved the model by augmenting the power of inflation and obtained a quadratic model.

5.2. Quadratic model estimation results

To improve the quadratic model, we used the Dynamic Least Squares (DOLS) method, which involves augmenting the cointegrating regression with lags and leads of changes in inflation so that the feedback in the cointegrating system is eliminated and we found the following results:

Table 6: Estimation of the quadratic equation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INF	1.940777	0.488299	3.974566	0.0106
INF^2	-0.161867	0.047656	-3.396606	0.0193
C	3.155146	1.279854	2.465239	0.0569
R-squared	0.976676	Mean dependent var		7.636875
Adjusted R-squared	0.855392	S.D. dependent var		2.573672
S.E. of regression	0.978701	Sum squared resid		4.789280
Durbin-Watson stat	3.228867	Long-run variance		0.196869

All coefficients are statistically significant and the representation of the estimated quadratic equation is:

$$GDP = 1.94*INF - 0.16*INF^2 + 3.16 \quad (4)$$

The positive sign of α_1 (+1.94) indicates that, at lower levels of inflation, there is positive relationship between GDP growth and inflation while the negative sign of α_2 (-0.16) point to a negative relationship between the two variables at higher levels of inflation. This means that the positive relationship between GDP growth and Inflation, at lower inflation levels, was transformed into a significant negative relationship for high inflation levels. Thus, at more than 5.9%, inflation begins to negatively affect growth. This is a clear indication of the existence of a turning point beyond which inflation becomes harmful to economic growth in Rwanda.

Using the simple rule of optimization, namely the necessary (or first order) and sufficient (or second order) conditions as shown below, the optimal inflation for GDP growth in Rwanda is estimated at 5.9%.

Indeed, to attain the maximum value of GDP growth, the first derivative of the function (4) must be zero at a given point of inflation (first order condition).

$$\left.\frac{\partial gdp}{\partial Inf}\right|_{Inf = Inf^*} = 0$$

$$\frac{\partial gdp}{\partial Inf} = 1.94 - 2*0.16*Inf = 0 \Longrightarrow Inf^* = \frac{-1.94}{-0.16*2} = 5.9$$

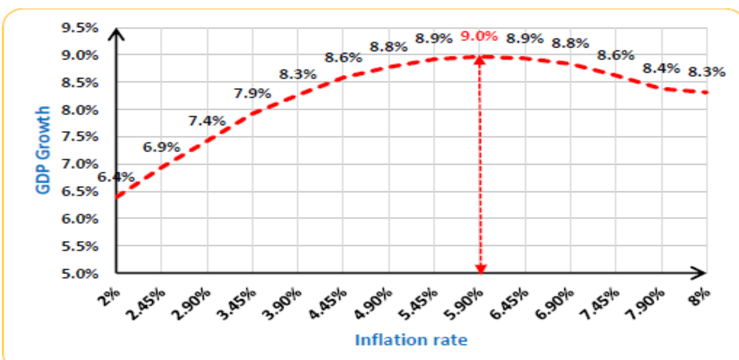
Inf* = 5.9%, to be the optimum value, the second derivative of the function must be negative (second order condition); implying that the slope of the function is decreasing at that level of inflation.

$$\left.\frac{\partial^2 gdp}{\partial Inf^2}\right|_{Inf = Inf^*} < 0$$

$$\frac{\partial^2 \mathrm{gdp}}{\partial Inf^2} = -0.16 < 0$$

As illustrated on the graph below from the estimated quadratic equation, in long run, at the optimum inflation rate of 5.9%, GDP growth will stand at 9.0% while when other factors are held unchanged, an increase in inflation by 1% beyond the optimum level negatively affects GDP growth by 0.2%.

Figure 4: GDP growth and Inflation using the estimated quadratic equation



From the results of the model, we also observed that below an inflation rate of 5.9%, the Rwandan economy will continue performing well but will fail to maximize economic growth. Therefore, instead of setting the medium term inflation objective at 5% with the only objective of achieving low inflation rate, the National bank of Rwanda should also consider the level of inflation, which can help to maximize economic performance.

VI. CONCLUSION AND POLICY RECOMMENDATIONS

The National Bank of Rwanda will shift from monetary targeting to a more forward-looking price-based monetary policy framework by December 2018. Just as before, the focus will be on keeping inflation low and stable. As per the convergence criteria, keeping inflation below the 8.0% ceiling is required to stabilize the EAC economies and facilitate the future formation of a monetary union. In addition, maintaining low and stable inflation will continue to support the Government's policies aimed at promoting economic growth. To ensure macroeconomic stability, it is necessary to estimate a threshold level of inflation, beyond which economic growth starts to decline. This serves as a guideline for policymakers to know the limits within which monetary policy can support growth.

In view of the above, this paper investigated whether there is an optimal level of inflation for economic growth in Rwanda using quarterly data from 2007 to 2017. The estimated models indicate the existence of a non-linear relationship between GDP growth and inflation in Rwanda and the optimal level is estimated at 5.9%.

The findings of this study support the fact that the 5.0% medium-term inflation objective has contributed to macroeconomic stability in Rwanda over the past years. However, the abovementioned inflation threshold can yield an additional 0.2% growth in GDP, keeping other factors constant.

REFERENCES

Busetti, F., L. Forni , A Harvey & F. Venditti. 2006. "Inflation convergence and divergence within the European Monetary Union". *International Journal of Central Banking*, Vol 3(2): 95-121.

Dornbusch, R., S. Fischer and R. Startz. 1996. *Macroeconomics* (7th edition). Singapore: Irwin/McGraw-Hill.

Drukker D., P. Gomis-Porqueras and P. Hernandez-Verme 2005. "Threshold effects in the relationship between inflation and growth: A New Panel-Data Approach", MPRA Paper 38225, University Library of Munich, Germany.

Fabayo, J. A. and O. T. Ajilore. 2006. "Inflation: How Much is Too Much for Economic Growth in Nigeria". *Indian Economic Review*, Vol. XXXXI(2): 129-147.

Frimpong J.M. and E.F. Oteng-Abayie 2010. "When is Inflation Harmful? Estimating the Threshold Effect for Ghana". *American Journal of Economics and Business Administration* Vol. 2: 232-239.

Gillman, M., M. Harris , and L. Matyas.2001. "Inflation and Growth: Some Theory and Evidence". Central European University Working Paper No. 1/2001.

Gordon, R. 1997. "The Time Varying NAIRU and Its Implications for Economic Policy". *Journal of Economic Perspectives*, Vol. 11(1): 11–32.

Gonzalo, J. and J. Pitarakis. 2002. "Estimation and Model Selection Based on Inference in Single and Multiple Threshold Methods". *Journal of Econometrics*, Vol. 110: 319-352.

Hansen, B. 1999. "Threshold Effects in Non-dynamic Panels: Estimation, Testing and Inference". *Journal of Econometrics*, Vol. 81: 594-607.

Hosny, A., M. Kandil and H. Mohtadi. 2014. "What does Egypt's Revolution Reveal about its Economy?" *International Economic Journal*, Vol. 28(4): 589-611.

Huybens, E. and D. S. Bruce. 1998. "Financial Market Frictions, Monetary Policy, and Capital Accumulation in a Small Open Economy", *Journal of Economic Theory* Vol. 81(2): 353-400.

Jiranyakul, K. 2017. "Estimating the Threshold Level of Inflation for Thailand", MPRA Paper No. 79661.

Khan, M. S. and A.S. Senhadji.2000. "Threshold Effect in the Relationship between Inflation and Growth". *IMF Staff Papers,* Vol. 48 (1): 1-21.

Leshoro, T.L.A. 2012. "Estimating the inflation threshold for South Africa". *Studies in Economics and Econometrics*, Vol. 36(2): 53-65.

Morar, D. 2011. "Inflation threshold and nonlinearity: Implications for inflation targeting in South Africa". Unpublished Thesis, Master of Commerce, Rhodes University.

Mubarik, Y. A. 2005. "Inflation and Economic Growth: An Estimation of the Threshold level of inflation in Pakistan". *State Bank of Pakistan Research Bulletin*, Vol. 1(1): 35-44.

Mundell, R. 1965. "Growth, stability and inflationary finance". *Journal of Political Economy*, Vol. 73: 97–109.

Musoni J. R. 2015. "Threshold Effects in the Relationship between Inflation and Economic Growth: Evidence from Rwanda". AERC Research Paper 293.

Nazir S., S. Saeed and A. Muhammad 2017. "Threshold Modeling for Inflation and GDP Growth", MPRA Paper No. 79649.

Ndoricimpa A. 2017. "Threshold Effects of Inflation on Economic Growth in Africa: Evidence from a Dynamic Panel Threshold Regression". African Development Bank Group. Working Paper No. 249.

Nkume J.B. and H. Ngalawa. 2014. "Optimal Inflation Threshold for Economic Growth in Malawi". *Journal of Economics and Behavioral Studies*, Vol. 6(12): 933-946.

Phetwe M. and L. Molefhe. 2016. "Inflation and Economic Growth: Estimation of a Threshold level of Inflation in Botswana". *The Research Bulletin*, Vol. 29(1): 13-23.

Sidrauski, M. 1967. "Rational Choice and Patterns of Growth in a Monetary Economy". *American Economic Review*, Vol. 57(2): 534-544.

Stockman, A. C. 1981. "Anticipated Inflation and the Capital Stock in a Cash-in-Advance Economy", *Journal of Monetary Economics*, Vol. 8 (3): 387-393.

Timsina N., R. K. Panta, M. Dangal and C. Mahesh. 2017. Optimal Inflation Rate for Nepal, Nepal Rastra Bank, Working Paper series, NRB-WP-39.

Tobin, J. 1965. "Money and economic growth". Econometrica, Vol. 33: 671–684

MODELLING AND FORECASTING INFLATION DYNAMICS IN RWANDA

Bruno MWENESE[8] **Aimé Placide KWIZERA**[9]

[8] Bruno Mwenese is a Senior Economist in the Research Department at National Bank of Rwanda

[9] Aime Placide Kwizera is an Economist in the Research Department at National Bank of Rwanda

ABSTRACT

Since 2009, National Bank of Rwanda (BNR) embarked on developing forecasting models to support evidence-based decision-making and enhance the forward-looking aspect of monetary policy. This paper focuses on the modelling and forecasting work at BNR, the models that are used and their purposes. Non-structural models such as ARIMA and State-Space models are used for short-term forecasting, while a small-scale New-Keynesian macroeconomic model called Forecasting and Policy Analysis System (FPAS) is used for medium-term projections. While the power of non-structural models reduces in presence of shocks, the FPAS performs well in terms of out of sample forecasting and building a consistent story for the whole economy. The results from the non-structural models can be replicated using the EViews programs provided in appendices.

Keywords: Inflation forecasting; non-structural models; FPAS; Rwanda.

JEL Classification: C51, C53, E31, E37

I. INTRODUCTION

Price stability is a prime objective for monetary authorities in most economies and monetary unions around the world (King, 2005). There are different reasons for that. Price instability causes uncertainty that induces high social and business costs, discourages investments, and distorts the price mechanism. Furthermore, price instability can generally jeopardize the entire macroeconomic stability (Bonato, 1998). To prevent the aforementioned undesirable outcomes of price instability, central banks require proper understanding of the future path of inflation to anchor expectations and ensure policy credibility; the key aspects of an effective monetary policy transmission mechanism (King, 2005).

To achieve these objectives, central banks in advanced economies adopted forward-looking monetary policy approach. A forward-looking monetary policy in modern-era central banks relies on two important functions: a modelling and forecasting function and a communication function. Compared to other monetary policy frameworks, the communication function is more emphasized in forward-looking monetary approach. It involves informing the public about events that guide policy decision-making and the outcomes of the policy decisions. This increases transparency and enhances credibility.

The modelling and forecasting function puts more emphasis on understanding key processes that are necessary for monetary policy decisions. The function gathered much acceptance that many central banks working under different monetary policy frameworks embraced it. This function requires putting in place several models, from simple econometric models to macroeconomic models that are useful for different purposes.

In Rwanda, National Bank of Rwanda (BNR) initiated the modeling and forecasting function in 2009 with the objective of feeding the monetary policy process with evidence based information. The need was strengthened with the defiance of the prevailing monetary targeting framework, stressing the importance of developing modelling and forecasting capacity as the economy moves into interest rate-based framework. Currently, the BNR has adopted and adapted several modelling and forecasting tools. For near-term forecasting, economists at BNR use autoregressive moving average (ARMA), vector auto-regressive (VARs and BVARs) and state-space models. For medium term forecasting, BNR has adapted the Forecasting and Policy Analysis System (FPAS) and developed its own (in-house) core model of inflation (CMI).

The purpose of this paper is to document the inflation modelling and forecasting work at BNR. The aim is to expound the building blocks and performance of the workhorse model used in forecasting inflation. The paper is intended to serve as a reference guide for internal modelling function and to share the experience with other central bank economists.

The rest of the paper is organized as follows: section 2 provides a brief situational analysis and the outlook design of inflation in Rwanda. Section 3 covers the theoretical foundations and approaches to modelling inflation. Section 4 introduces the methodology of the inflation models in the BNR. Section 5 analyzes and interprets results while section 6 concludes.

II. SITUATIONAL ANALYSIS AND OUTLOOK DESIGN OF INFLATION IN RWANDA

The data used to model and forecast inflation come from two complementary sources. In collaboration with BNR, the National Institute of Statistics of Rwanda (NISR) collects survey data for computing Consumer Price Index (CPI). The CPI Survey takes place in the first and the third week of each month. Each month, a new CPI is produced and released on 10th of the following month. Data collection covers the entire country under different components as per the international classification of the CPI. Although less frequent, the covered products and weights change based on the results of a survey on consumer basket carried out every three years.

Table 1: CPI components and weights

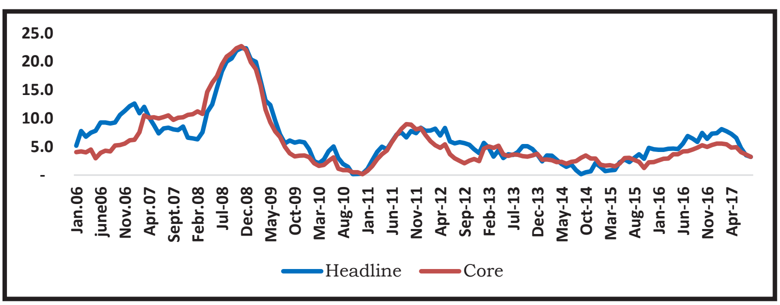
CPI Component	Weight
01. Food and non-alcoholic beverages	27.4
02. Alcoholic beverages and tobacco	4.9
03. Clothing and footwear	5.3
04. Housing, water, electricity, gas and other fuels	20.8
05. Furnishing, household equipment and routine household maintenance	3.8
06. Health	1.3
07. Transport	12.5
08. Communication	3.1
09. Recreation and culture	3.1
10. Education	2.7
11. Restaurants and hotels	8.8
12. Miscellaneous goods and services	6.4
GENERAL INDEX	100.0

Source: NISR (2017)

BNR uses three main categorizations in inflation analysis. The first categorization comprises twelve components. In terms of weights and contribution to CPI inflation, the three key components of CPI basket include: Food (currently weighting 27.4% in the CPI basket), Housing (with 22% weight) and Transport (with 17.4% weight) (see Table 1). These components are composed of the most volatile items, including fresh food products and energy products such as fuels and lubricants, firewood and charcoal. Over the last 10 years, the three main components have accounted for above 70% of variations in the CPI inflation.

Two other important categorizations used include: (i) domestic vs. imported inflation, and (ii) headline vs core inflation (also referred to as underlying inflation). The analysis of imported inflation is important because this category reflects the effects of exchange rate, a macroeconomic variable closely monitored by BNR. There are co-movements between headline inflation and core inflation and between headline inflation and domestic inflation. Except in periods of high short-term volatility, the trend in one component could provide information on trends in the other, at least in the medium-term.

Figure 1: Headline and Core Inflation (year-on-year, % change)



Source: Authors

The data from CPI Surveys are supplemented by data from Price Expectations Survey (PES) conducted by BNR. PESs have two main modules. The first one is the food and energy price expectations survey (FEPES) that focuses on three CPI components identified to have been influencing the path of the overall CPI. These include Food items (vegetables), Transport items (cars, oil and transport fares) and Energy (firewood and charcoal). The survey is carried out in districts where the items are mostly produced, targeting cooperatives and farmers. The survey also collects information from key importers and exporters of the items in the three CPI components. The information collected during FEPES focuses on anticipated or expected production and price changes on a one to two-month horizon. The second module of PES is the market expectations survey (MES) covering major manufacturing companies in Kigali City whose products are mostly classified under core CPI, i.e. products whose price do not vary frequently and are not likely to influence the CPI trends in the short-run.

Outlook analysis is conducted for the short-run and medium term based on model forecasts, results from the PESs, and other off-model information about economic activities that cannot be explicitly modeled. Short-run model forecasts are done either on headline inflation or on individual components which are then aggregated to produce headline forecasts. Medium-term macro-econometric models focus on both headline and core inflation. The latter mimics the aggregate demand, and is of most importance for monetary policy.

III. LITERATURE REVIEW

This study distinguishes two categories of forecasting models of price behavior or inflation: macroeconomic models elaborated by or from different economic schools of thought and econometric models purely based on empirical considerations. Two schools of thought dominated the modern macroeconomics: New-Classical and New Keynesian. Generally, the main purpose of these schools of thoughts is to understand macroeconomic activity, mostly the nation's output and its links with other macroeconomic variables and related policies. Inflation, an important macroeconomic variable, keeps attracting attention in the dichotomy between the classical and the Keynesian. This brief review focuses on forecasting by new-Keynesian models that seem to be more popular among scholars on the basis of their simplicity and realism. It also covers non-structural econometric models namely auto regression moving average (ARMA) and state-space models.

Forecasting a variable by non-structural auto-regressive models consists of assuming that a univariate time series' variable depends on a weighted average of its past values and a random shock. There is no conditions or prior values. The quality of the forecast improves when policy remains unchanged and the forecasting horizon is not subject to acute exogenous shocks (Prescatori and Zaman, 2011). In this case forecasting is built on a stochastic trend that changes every time when new data come in; consequently jeopardizing an effective long run forecasting.

A longer forecasting horizon can be well handled by macroeconomic models built around business cycles such as the New-Keynesian model. A simplified version of new Keynesian model for a central bank in an open economy has four core behavioral equations: (i) output (gap) equation (aggregate demand), (ii) inflation equation (Phillips-curve), (iii) policy reaction function (interest rate equation) and (iv) exchange rate based on modified risk-adjusted uncovered interest parity (UIP).

The aggregate demand equation postulates that consumption follows an inter-temporal optimization pattern similar to the one of real business cycle models facing a period budget constraint with sticky prices on labor, financial and goods markets. This gives the following Euler or IS equation:

$$\tilde{y}_t = \widetilde{E_t}\widetilde{y_{t+1}} - \tilde{r}_t \tag{1}$$

Where $\tilde{y}_t$ is output gap and $r_t$is real interest rate,

The production operates in a monopolistic competition where firms' prices are equal to the marginal cost plus a markup. That is:

$$\pi_t = \sum_{k=0}^{\infty} \beta^k E_t(mc_{t+k}) \tag{2}$$

Where $\pi_t$is inflation and $mc_{t+k}$is marginal cost.

The Phillips curve departs from the firm's price setting behavior. The idea is that inflation can be modeled as a function of output, but the most important assumption here is that prices do not fall to market clearing levels (Greenwald and Stiglitz, 1987). In this case, inflation fluctuations depend on the firms' desired markup vis-à-vis the economy's average markup. Subsequently, the inflation is subject to fluctuations that do not necessarily come from a monetary policy change. However, policy rate is adjusted to respond to future inflation and output deviations in a forward-looking specification. Nevertheless, the empirical evidence finds that a specification with both backward- and forward-looking terms provides the best fit to the data (Rummel, 2015).

The monetary policy reaction function describes the way monetary policy is set by a monetary authority. In macroeconomic-modelling the behavior of central bank, this function is also the closure rule. This behavior is captured by introducing an equation on interest rate, which is the instrument of monetary policy.

$$i_t = \rho + \varphi_\pi \widetilde{\pi_{t+1}} + \varphi_y \widetilde{Y_t} + V_t \quad (3)$$

where i_t is short-term domestic interest rate, $\widetilde{\pi_{t+1}}$ is expected inflation deviation $\widetilde{Y_t}$ is output gap and V_t is policy shock.

This equation posits that the monetary authority is assumed to respond to deviations of next period inflation from its target and to the output gap as shown in the simplified equation. In other words, economists assume that money-market rates flawlessly transmit changes in the policy rate into credit markets.

The last period policy stance affects the current policy stance allowing the authority to smooth interest rates by adjusting them gradually to the desired level implied by the deviations of inflation and output from equilibrium.

To take into account the effect of the world economy, the modelling and the forecasting exercise incorporates a foreign sector in the model by including an equation on exchange rate. It is agreed that exchange rate is the price that equilibrate foreign exchange markets. In modern economics, the stock-equilibrium approach to exchange rate determination posits that the supply and demand of exchange rate are trade-unrelated; financial assets dominate them. Therefore, exchange rate can be modelled through the UIP that focus on capital market, unlike the purchasing power parity that focus on goods market. Algebraically, the UIP states that

$$s_t = E_t s_{t+1} - (i_t - i_t^* - prem_t)/4 + e_t \quad (4)$$

where st is nominal spot exchange rate, it is domestic interest rate, it* is foreign interest rate, prem is risk premium, and et is an error term. It is a pure forward-looking version relating the behavior of domestic and foreign interest rates, and the nominal exchange rate.

The New Keynesian model allows expressing each variable in terms of its deviation from equilibrium, in other words in "gap" terms. The model itself does not attempt to explain movements in equilibrium real output, or real exchange rate, or real interest rate, nor in inflation target. Rather, these are taken as given from various sources employing filtering methodologies or using the analyst judgment and views about these equilibrium values (Leeper, 2003).

IV. ANALYTICAL APPROACHES

This section outlines the main approaches[10] used by BNR to forecast inflation. It covers the univariate time series models used for short-term forecasting such as ARIMA on headline inflation, disaggregated ARIMA on components of CPI inflation and the state space models on components. Since inflation is a multi-faceted phenomenon, it can be advantageous to study it considering different markets and their interactions to be able to capture as much information as possible (Jansen, 2004). Therefore, this section also includes FPAS, a macro-model used for medium-term forecasting. The model covers the basic sectors of the economy.

4.1. Short-term inflation forecasting

4.1.1. ARIMA model for headline inflation forecasting

The ARIMA that is estimated is akin to Jalles (2009):

$$Y_t = \emptyset_1 Y_{t-1} + \cdots + \emptyset_p Y_{t-p} + \mu_t + \delta_t + \gamma_t + \varepsilon_{i,t} \text{ Where } t = 1, \ldots, T \text{ and } i = 1, \ldots, p \quad (5)$$

With $$Y_t = \begin{pmatrix} y_1 \\ \cdot \\ \cdot \\ \cdot \\ y_T \end{pmatrix}, \mu_t = \begin{pmatrix} \mu_{1,t} \\ \cdot \\ \cdot \\ \cdot \\ \mu_{p,t} \end{pmatrix} \quad \delta_t = \begin{pmatrix} \delta_{1,t} \\ \cdot \\ \cdot \\ \cdot \\ \delta_{p,t} \end{pmatrix} \quad \gamma_t = \begin{pmatrix} \gamma_{1,t} \\ \cdot \\ \cdot \\ \cdot \\ \gamma_{p,t} \end{pmatrix} \quad \varepsilon_t = \begin{pmatrix} \varepsilon_{1,t} \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_{p,t} \end{pmatrix}$$

Y_t is the dependent variable, i are lags, μ Represents the trend, δ the cycle, γ the seasonal component and ε is the error term. The best linear predictor, in terms of yielding the minimum mean squared error (MSE), of Y_{t+1} (or one-step-ahead forecast) based on information available at time t is:

[10] The stock of models provided here is not fully exhaustive to reflect all the models used at the BNR

$$Y_{t+1|t} = \emptyset_1 Y_t + \cdots + \emptyset_p Y_{t-p+1} \quad (6)$$

The corresponding forecast error is given by:

$$Y_{t+1} - Y_{t+1|t} = \varepsilon_{t+1} + \vartheta_1 \varepsilon_t + \cdots + \vartheta_p \varepsilon_{t-p+1} \quad (7)$$

The ARIMA is assumed to provide relatively good forecasts only in the short-run and the precision wanes as one moves into distant future. It is used as a benchmark model against which other models are evaluated (Harvey, 2012).

Empirically, BNR estimates the following equation in E-views:

equation eqn_headline.ls d(HEADLINE) c d(HEADLINE(-1)) @seas() @trend

where "eqn_headline" is the name given to the headline inflation. Note that here the time series is expressed as inflation instead of the index. The forecast is then obtained by estimating the subsequent equation:

eqn_headline.forecast headlinef

4.1.2. ARIMA model for forecasting disaggregated components of headline inflation

There exist three approaches to forecast aggregate series from components. According to Harvey (2012) one approach is to model the subcomponents independently and aggregate the forecast from independent models using their respective weights in the CPI basket. A second approach is to model the subcomponents jointly in a vector auto-regression (VAR) and aggregate individual forecasts into an aggregate forecast. A third approach is to use disaggregated components in an aggregate model and forecast the aggregate directly. At BNR, this model referred to as Short Term Inflation Forecast (STIF) is estimated using OLS. A time-series model is constructed in EViews for each CPI component. As an example, in EViews the health component is given by:

eqn_health.ls d(HEALTH) c d(HEALTH(-1)) @seas(1) @seas(2) @seas(3) @trend.

Then, each model is used to produce a short-term forecast for the respective CPI component as follows (see the regression and the forecast EViews programs in appendix A):

eqn_health.forecast healthf

The model re-aggregates individual forecasts into CPI, using the weights of each component in the CPI basket. That is:

$$CPIF = (\text{weights}(1) * \text{foodf} + \text{weights}(2) * \text{alcoholicf} + \text{weights}(3) * \text{clothingf} + \text{weights}(4) * \text{housingf} + \text{weights}(5) * \text{furnishingf} + \text{weights}(6) * \text{healthf} + \text{weights}(7) * \text{transportf} + \text{weights}(8) * \text{communicationf} + \text{weights}(9) * \text{recreationf} + \text{weights}(10) * \text{eductionf} + \text{weights}(11) * \text{restaurantsf} + \text{weights}(12) * \text{miscellaneousf})/100 \quad (8)$$

For some scholars, forecasting using disaggregated components should perform better than direct forecasts as it includes more information. This is, however, an empirical issue given that many studies found mixed results (Rummel, 2015).

4.2. The State-Space Model

The rationale for using the state space model is that most economic variables have unobservable components and some may have time-varying parameters. State-space models use the Kalman filter that takes care of those issues by separating and allowing the unobservable state variables to be estimated along with the observed signal variables. In this case, the headline inflation can be modeled as a weighted sum of the dynamics state-space functions of the 12 components. This can be represented in a matrix form as follows:

The observation equation is given by

$$y_t = H_t \beta_t + A_t Z_t + \varepsilon_t, \quad (9)$$

The state equation is

$$\beta_t = \mu_t + F_t \beta_{t-1} + v_t \quad (10)$$

Where y_t is an (n × 1) vector of observable variables, H_t is an (n × m) matrix, $Z_t$is an (n × k) matrix of exogenous variables, $\beta_t$is an (m × 1) vector of unobservable state variables, $A_t$is a (k × n) matrix of parameters and ε_t and $v_t$are disturbance terms which may be contemporaneously correlated.

4.3. Forecasting and Policy Analysis System (FPAS)

FPAS is a system for regular data collection and analysis to support monetary policy decisions and implementation. As a system, FPAS is composed of different elements: (i) a core macroeconomic model covering four main sectors of the economy, (ii) some working processes and institutional structure, (iii) a forecasting team composed of modelers and sectoral experts, and (iv) mechanisms for data management and communication.

FPAS offer several advantages. It is a comprehensive way to analyze the behavior of the economy and provides a good story-telling capacity. It is also a powerful tool for medium-term forecasting, and enables taking into account expectations and captures monetary policy reactions as endogenous. It gives the possibility of performing alternative policy scenarios and quantification of uncertainties and it is a good framework for communication to the public.

FPAS is in class of reduced-form new-Keynesian models that can be calibrated to fit stylized facts in most countries and to prepare an inflation forecast. The objective of this class of models is to help decide on an appropriate level of the policy interest rate, given the inflation target and the state of the economy (Berg, Karam and Laxton, 2006).

For the purpose of this documentation, here we present a succinct introduction of the four basic equations of the model and the modifications and additions that were made to get to its current shape. The equations are: the IS curve, the Phillips curve, the UIP condition and the monetary policy reaction function. However, it is important to note that the model, in its current shape, is still subject to some changes to reflect further the realities of the Rwandan economy. It is worth noting that using FPAS involves three main aspects that are not explained in this paper. These include (i) calibration, (ii) testing of model properties and data preparation and forecasting, and (iii) results analysis and interpretation. It is also important to note that our current model also includes a block for foreign variables, a fiscal block and a block for foreign aid.

The IS curve

The output gap which approximates the IS curve describes the aggregate demand relations in the economy and is defined as a function of the Real Monetary Conditions Index ($rmci$), the foreign output gap/demand ($l\_y\_foreign\_gap$) as well as past output gap ($l\_y\_nonagr\_gap_{t-1}$), fiscal impulse ($fimp_{t-n}$) and foreign aid (aid). The output gap is used here as a representation of aggregate demand and is linked with inflation given that excess demand pushes up inflation. It is stated as:

$$l\_y\_nonagr\_gap = \alpha_1 l\_y\_nonagr\_gap_{t-1} - \alpha_2 rmci + \alpha_3 l\_y\_foreign\_gap + \alpha_4 fimp_{t-n} + \alpha_4 aid + shock\_l\_y\_nonagr\_gap \quad (11)$$

The fiscal impulse represents the effect of the fiscal sector on economic activity. It is captured by the changes in structural deficit. Although the percentage of aid in the budget declined, aid still represents a considerable percentage; hence the rationale to directly model aid in the aggregate demand equation.

The supply curve

BNR started with a simple version of the Phillips curve which assumes that headline inflation depends on its lagged term (π_{t-1}^{core}), expected inflation ($E_t\pi_t$), the real marginal costs (rmc^{core}) and the supply or inflation shock (ε^{core}). Subsequent developments led to the separation between core inflation and non-core (volatile) inflation. Headline inflation is then derived as an identity using the respective weights of core and non-core components. The model includes the effect of imported food prices to inflation ($food\_imp_{t-1}$) and of international oil prices (oil_imp_{t-1}), and of relative prices between core and non-core prices (rp).

$$\pi^{core} = \beta_1 \pi_{t-1}^{core} + \beta_2 E_t \pi_t + \beta_3 rmc^{core} + \beta_4 food\_imp_{t-1} + \beta_5 \pi_{t-1}^{for} + \beta_6 rp + \varepsilon^{core} \quad (12)$$

$$\pi^{noncore} = \beta_1 \pi_{t-1}^{noncore} + \beta_2 E_t \pi_t^{noncore} + \beta_3 rmc^{noncore} + \beta_4 food\_imp_{t-1} + \beta_5 oil\_imp_{t-1} + \beta_6 \pi_{t-1}^{for} + \beta_7 rp + \beta_8 l\_y\_gap + \varepsilon^{core} \quad (13)$$

The foreign exchange rate rule

The rule is used to provide a link between the domestic and external economies through the exchange rate. The nominal exchange rate (s_t) is assumed to depend on policy actions on foreign exchange market and on market forces. The policy interventions are function of the position vis-a-vis the desired level of depreciation (Δs^{tar}), the inflation deviations (π^{dev}), the real exchange rate gap ($\hat{z}$) and the gap in the foreign aid (aid_{gap}). The market exchange rate is influenced by the expectations of nominal exchange rate in a period of two quarters ahead (s_t^{uip}), the interest rate differentials ($i - i^{us}$), the country's risk premium ($prem$) and the movements in aid inflows (aid_gap_ann).

$$\Delta s_t^{policy} = \Delta s^{tar} + \gamma_1 \pi^{dev} + \gamma_2 \hat{z} + \gamma_3 aid_{gap} + \varepsilon^{policy} \quad (14)$$

$$s_t^{uip} = E s_{t+2} - (i - i^{us} - prem)/4 - \delta_1 aid\_gap\_ann + \varepsilon^{uip} \quad (15)$$

$$\Delta s_t = w^{policy} * \Delta s_t^{policy} + \left(1 - w^{policy}\right) * \Delta s_t^{uip} \quad (16)$$

Where w^{policy} is the weight of policy interventions in exchange rate determination.

The monetary policy rule

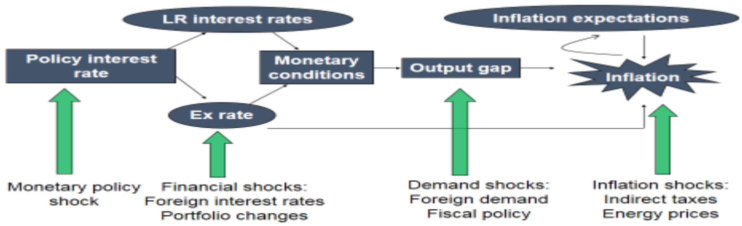
The model is closed by a policy reaction function. The central bank's reaction function is defined by the monetary policy rule in which movements in the nominal interest rate (ip) is assumed to depend on its own lag (ip_{t-1}), the neutral interest rate (ip_neutr), the inflation deviation from the target (π^{dev}), the output gap (l_y_gap), the nominal depreciation deviation from the target (${\Delta s_t}^{dev}$) and the monetary policy shock (ε^{ip}). The monetary policy rule equation is stated as:

$$ip = \theta_1 ip_{t-1} + \theta_2\left(ip\_neutr + \theta_3 \pi^{dev} + \theta_4 l\_y\_gap + \theta_5 {\Delta s_t}^{dev}\right) + \varepsilon^{ip} \quad (17)$$

With $ip = w^{tb} tb + (1 - w^{tb}) ib$ where tb is 91-day T-bill nominal interest rate, ib is the interbank interest rate and $w^{tb}$is the weight of T-bills rate in the market interest rate determination.

The four basic equations are linked to one another through the satellite equations and identities that engender the main variables based on the transmission mechanisms embedded in the model. Our FPAS model assumes three key channels namely the interest rate channel, the expectations channel and the exchange rate channel. Figure 2 schematically describes those relationships (for more please see Karangwa and Mwenese, 2015).

Figure 2: Monetary policy transmission mechanisms



The model assumes that some direct effects on inflation can come from exchange rate (e.g. aid shock), or an inflation shock (e.g. changes in energy prices), or variations in inflation expectations. The indirect effects pass through output gap and can further arise from a change in monetary policy, exchange rate or from aggregate demand.

V. MODEL OUTPUTS

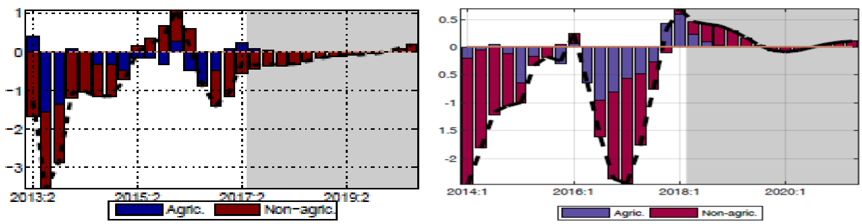
In this section, we present key outputs from the three models, focusing on out-of-sample forecasts. However, we focus on FPAS as the workhorse model as far as monetary policy process is concerned. Model outputs from ARIMA and state-space models are used for benchmarking in short-run and obtaining near-term forecasts (NTFs). For the medium-term, the horizon of the monetary policy committee, FPAS model results are used (see appendix C). It is also important to note that, despite the fact that model outputs are ultimately used for guiding discussions about the trends of macroeconomic variables, off-model information are also considered.

New information and incoming data affect the starting point and the dynamics of the forecasts. To demonstrate that, we compare two FPAS outputs from the 2017Q2 and 2018Q1 forecast rounds.

Output (GDP)

In the 2017Q2 forecast round, projected output gap suggested that aggregate demand would be picking up but still weak, inducing no inflationary pressures from domestic demand in 2017Q3 through to 2018Q1 (see graph on the left in Figure 3). The economy was expected to record a good performance compared to 2017Q1, backed by improving non-inflationary aggregate demand, increasing international commodity prices and low depreciation of the FRW.

Figure 3: Real GDP Gap, the 2017Q2 (left) and 2018Q1 (right) forecast rounds

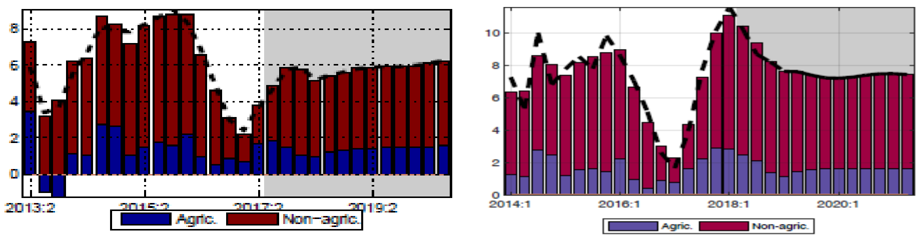


Source: Research Department, BNR

During 2017Q1, growth in agriculture production was subdued on account of unfavorable weather conditions. Growth in non-agriculture activities also realized a lower growth resulting from diminishing performance in the construction sub-sector. However, economic activities signaled an improvement over the four quarters ahead with growth expectation evolving around 4.0%, 4.8%, 5.9% and 6.1% in 2017Q2, 2017Q3, 2017Q4 and 2018 Q1, respectively.

The 2018Q1 forecast round corroborated this upward trend although the actual growth was higher than projected in 2017Q2. The higher growth came from improved food production and good performance of the mining sector following favorable weather conditions and increased international mineral prices respectively. The three quarters in between the two forecast rounds brought in new data and new information that changed the initial conditions (or the starting point) for forecasting as well as the forecast itself. Subsequently, the projected growth shifted above 6% (see Figure 4).

Figure 4: Real DGP Growth, the 2017Q2 (left) and 2018Q1 (right) forecast rounds (%, Y-o-Y)

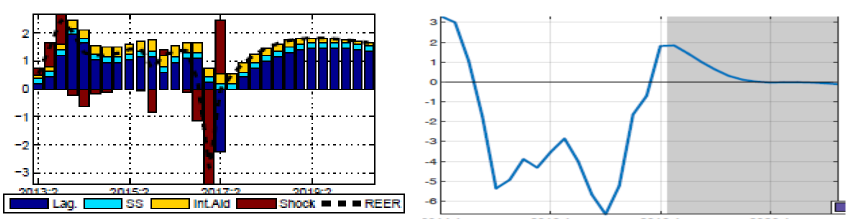


Source: Research Department, BNR

Exchange rate

Consistent with the prevailing domestic and global challenges, the FRW depreciation accelerated in 2016, lowering the Franc overvaluation (see Figure 5). In 2017, the depreciation decelerated and was expected to keep this trend over forecast horizon especially in 2017Q4 and 2018Q1. This was in line with the expected recovery in international commodity prices that led to increased export receipts in Rwanda. Moreover, import bill declined following the government initiative of boosting domestic production.

Figure 5: Real Exchange Rate Gap, the 2017Q2 (left) and 2018Q1 (right) forecast rounds

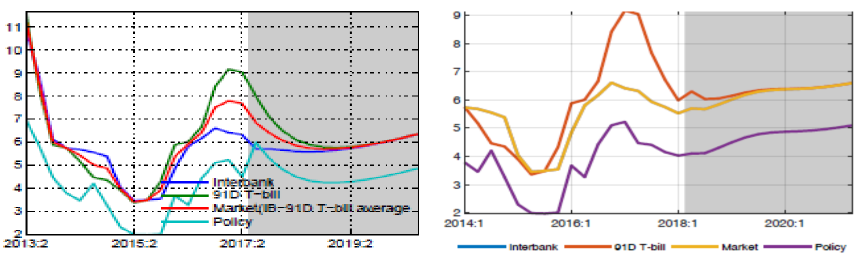


Source: Research Department, BNR

Interest rate

In response to expected deceleration in inflation in the medium-term (as seen in figure 6), the policy rate was revised down by 25 basis points in 2017Q2 and by 50 basis points in 2017Q4. Subsequently, money market interest rates decelerated. The 91-days T-bills rate and the interbank rate started decreasing from 9.2% and 6.4% in 2017Q2 to 9.0% and 6.3% in 2017Q3 respectively. This trend was estimated to stabilize in four quarters that followed. However, during the 2018Q1 forecast round, inflation was projected to pick up higher than projected in 2017Q2. This model output was suggestive of a tighter monetary policy stance.

Figure 6: Nominal interest rate (%), the 2017Q2 (left) and 2018Q1 (right) forecast rounds

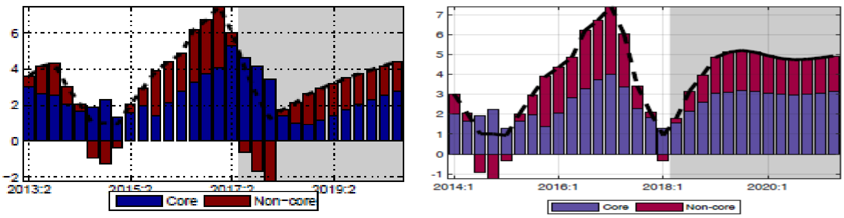


Source: Research Department, BNR

Inflation

During the 2017Q2 forecast round, inflation showed a decreasing trend over the forecast period from 6.2% in 2017Q2 to 4.2%, 2.5% and 1.3% in the 2017Q3, 2017Q4 and 2018Q1, respectively (see Figure 7). Reduced pressures on exchange rate and on international oil prices until the end of 2017Q4 pointed to limited effects of imported inflation coupled with expected mild improvement in economic activity. In addition, fresh food prices and energy prices were expected to ease in four quarters ahead, compared to the same period the previous year.

Figure 7: Headline inflation, the 2017Q2 (left) and 2018Q1 (right) forecast rounds (%, Y-o-Y)



Source: Research Department, BNR

The actual data in three quarters from 2017Q2 confirmed the forecasted trajectory with some differences in numbers. From 2018Q1, going forward the trajectory remains the same as projected in the 2017Q2. However, new forecast events expected in the horizon moved up the projected inflation.

Overall, from the precedent discussion based on FPAS, we are able to build a consistent story on the interactions among different sectors of the economy and how they drive inflation in the medium-term. For instance, in 2017Q2 we predicted that, with the mild improvement in economic activity, aggregate demand was expected to remain non-inflationary in 2018. Exchange rate depreciation was to decelerate because of low demand for imports. Therefore, inflation was likely to evolve below target and, in this context, monetary policy stance eased accordingly. The FPAS based results on inflation were in line with the forecasts from ARIMA and state-space models for 2017Q4, all pointing to a decrease in inflation from 2017Q3. Table 2 provides the forecasts of the headline inflation from the ARIMA and state-space models for October, November and December 2017.

Table 2: Short-run inflation Forecasts

	STIF-ARIMA	**STATE SPACE**	**ARMA on Headline**
Oct-17	1.9	1.9	2.9
Nov-17	2.0	2.2	2.9
Dec-17	1.5	2.3	2.7
2017Q4	1.8	2.1	2.8

Source: Authors

Before June 2016, ARIMA and state-space models were providing reliable forecasts in one to three-month horizon. After June 2016, the country experienced sharp supply shocks at different episodes and changes in policy rates, diminishing the forecasting power of these non-structural models.

So far, the FPAS model performs well in terms of explaining and providing a consistent story across all the sectors of the economy (Karangwa and Mwenese, 2015). It also does well in terms of out-of-sample forecasting. For instance, in 2016Q4 although it was a period of high inflation evolving above the target, the FPAS model, together with other off-model information projected that inflation would start decreasing in 2017Q2 and monetary policy stance was eased accordingly. This could seem paradoxical but inflation developments during that period confirmed those forecasts. Indeed, FPAS helped to bring together all the economic indicators needed by decision makers and built a strong case for policy guidance.

VI. CONCLUSION

Faced with the need to adopt an interest rate-based framework in an effort to enhance policy decision making in a forward-looking approach, BNR has developed models to forecast key macroeconomic variables, focusing mainly on inflation and its key drivers. The organization of forecasting work requires capacity building for economists. This paper comes in the spirit of documenting and sharing BNR's experience in modelling and forecasting inflation.

As briefly documented in this paper, BNR uses non-structural models such as ARIMA on headline, ARIMA on components and state-space for producing short-run inflation projections. In addition, BNR uses a small-scale New-Keynesian macroeconomic model called FPAS for medium-term forecasting. These models perform well in terms of projecting future paths of inflation. Currently, the FPAS macro-model is the main analytical framework through which monetary policy discussions are streamlined.

The results from non-structural models can be replicated using the EViews programs provided in appendices. However, it was not possible to reproduce here all the FPAS' scripts for replication. There remain some challenge pertaining to the use of United States and the Eurozone data to represent the effects of external economic developments on the domestic economy. A desirable option would be to use data from our main trading partners mostly EAC.

REFERENCES

Berg, A., P. Karam and D. Laxton. 2006. "A Practical Model-Based Approach to Monetary Policy Analysis-Overview". IMF Working Paper No. WP/06/81, International Monetary Fund, Washington D.C.

Bonato, L. 1998. "The Benefits of Price Stability: Some Estimates from New Zealand". Reserve Bank of New Zealand Bulletin Vol. 61(3).

Greenwald, B., and J.E. Stiglitz, 1987. "Keynesian, New Keynesian and New Classical Economics". *NBER Working Paper Series* No. 2160.

Harvey, A. C. 1989. *Forecasting, Structural Time series Models and the Kalman Filter*. Cambridge, Cambridge University Press.

Jalles, J.T. 2009. *Structural Time Series Models and the Kalman Filter: A Concise Review*. Cambridge, Cambridge University Press.

Karangwa, M. and B. Mwenese. 2015. "The Forecasting and Policy Analysis Systems (FPAS) Macro-model for Rwanda". *BNR Economic Review* Vol. 7: 101-129.

King, M. 2005. "Monetary Policy: Practice Ahead of Theory. Bank of England". *Mais Lecture of Economics and Finance* Vol. 3-4/2008.

Prescatori, A. and S. Zaman. 2011. "Macroeconomic Models, Forecasting and Policymaking". Economic Commentary No. 2011-19. Cleveland: Federal Reserve Bank of Cleveland.

Rummel, O. 2015. "Estimating a Monetary Policy Model for India". London, Bank of England.

APPENDICES

Appendix A: ARIMA on components

A-1 Regressions of the 12 CPI components

```
equation eq_alcoholic.ls alcoholic  c  alcoholic(-1)  @trend @seas(7) @seas(8)
equation eq_clothing.ls clothing c clothing(-1) @trend
equation eq_communication.ls  communication c communication(-1)  @seas(10)
equation eq_education.ls education c education(-1) @seas(1) @seas(2) @trend
equation eq_food.ls food c food(-1) food(-2)  @seas(3) @seas(5) @seas(8) @seas(12) @trend
equation eq_furnishing.ls furnishing c furnishing(-1) furnishing(-2)  @seas(6)
equation eq_health.ls health c  health(-1)
equation eq_housing.ls housing c housing(-1) @seas(3) @seas(6)
equation eq_miscellaneous.ls miscellaneous c miscellaneous(-1) miscellaneous(-2) @trend
equation eq_recreation.ls recreation c recreation(-1)  @seas(7) @trend
equation eq_restaurants.ls restaurants c restaurants(-1)
equation eq_transport.ls  transport c  transport(-1) transport(-2)   @seas(7)
```

A-2 Dynamic forecasts for the 12 CPI items: out of sample forecasts

```
smpl 2017m9 2017m12
eq_alcoholic.forecast alcoholicf alcoholicse
group a alcoholicf (alcoholicf-alcoholicse)  (alcoholicf+alcoholicse)
smpl 2004m1 2017m12
freeze(gr_alcoholic) a.line

smpl 2017m9 2017m12
eq_clothing.forecast clothingf clothingse
group cl clothingf (clothingf-clothingse) (clothingf+clothingse)
smpl 2004m1 2017m12
freeze(gr_clothing) cl.line

smpl 2017m9 2017m12
eq_communication.forecast communicationf communicationse
group com communicationf (communicationf-communicationse) (communicationf+communicationse)
smpl 2004m1 2017m12
freeze(gr_communication) com.line

smpl 2017m9 2017m12
eq_education.forecast educationf educationse
group educ educationf (educationf-educationse) (educationf+educationse)
smpl 2004m1 2017m12
freeze(gr_education) educ.line

smpl 2017m9 2017m12
eq_food.forecast foodf foodse
group fd foodf (foodf-foodse) (foodf+foodse)
smpl 2004m1 2017m12
freeze(gr_food) fd.line

smpl 2017m9 2017m12
eq_furnishing.forecast furnishingf furnishingse
group furn furnishingf (furnishingf-furnishingse) (furnishingf+furnishingse)
smpl 2004m1 2017m12
freeze(gr_furnishing) furn.line

smpl 2017m9 2017m12
eq_health.forecast healthf healthse
group heal healthf (healthf-healthse) (healthf+healthse)
smpl 2004m1 2017m12
```

```
freeze(gr_health) heal.line


smpl 2017m9 2017m12
eq_housing.forecast housingf housingse
group house housingf (housingf-housingse) (housingf+housingse)
smpl 2004m1 2017m12
freeze(gr_housing) house.line

smpl 2017m9 2017m12
eq_miscellaneous.forecast miscellaneousf miscellaneousse
group misc miscellaneousf (miscellaneousf-miscellaneousse) (miscellaneousf+miscellaneousse)
smpl 2004m1 2017m12
freeze(gr_miscellaneous) misc.line

smpl 2017m9 2017m12
eq_recreation.forecast recreationf recreationse
group recreat recreationf (recreationf-recreationse) (recreationf+recreationse)
smpl 2004m1 2017m12
freeze(gr_recreation) recreat.line

smpl 2017m9 2017m12
eq_restaurants.forecast restaurantsf restaurantsse
group rest restaurantsf (restaurantsf-restaurantsse) (restaurantsf+restaurantsse)
smpl 2004m1 2017m12
freeze(gr_restaurants) rest.line

smpl 2017m9 2017m12
eq_transport.forecast transportf transportse
group transp transportf (transportf-transportse) (transportf+transportse)
smpl 2004m1 2017m12
freeze(gr_transport) transp.line
```

Generate weights for the cpi items

```
vector(12) weights
weights.fill 2738,485,531,2075,375,133,1245,314,307,275,882,639
```

Make and solve model

```
smpl 2004m1 2017m12
model stif

stif.append cpif=(weights(1)*foodf + weights(2)*alcoholicf + weights(3)*clothingf + weights(4)*housingf +
weights(5)*  furnishingf  + weights(6)*healthf + weights(7)*transportf + weights(8)*communicationf +
weights(9)*recreationf + weights(10)*educationf + weights(11)* restaurantsf + weights(12)*miscellaneousf)/100

stif.solve
```

Calculate annual inflation rates: both actual and forecasts from cpif and cpi

```
genr dcpi=@pcy(cpi)

genr dcpif=@pcy(cpif_0)
```

Appendix B: STATE SPACE on components

B-1 State Space estimations of the 12 CPI components

```
smpl 2004m01 2017m12

param c(1) -2 c(2) -2 c(3) -2 c(4) -2 c(5) -2 c(6) -2 c(7) -2 c(8) -2 c(9) -2 c(10) -2 c(11) -2 c(12) -2 c(13) -2 c(14) -2
c(15) -2 c(16) -2 c(17) -2 c(18) -2 c(19) -2 c(20) -2 c(21) -2 c(22) -2 c(23) 0.9 c(24) 0.5 c(25) -2

sspace ss_alcoholic
ss_alcoholic.append @signal  alcoholic = mu + beta + [var=exp(c(1))]
ss_alcoholic.append @state mu = mu(-1) + beta(-1) + [var=exp(c(2))]
ss_alcoholic.append @state beta = beta(-1)
ss_alcoholic.ml

sspace ss_clothing
ss_clothing.append @signal  clothing = mu + beta + [var=exp(c(3))]
ss_clothing.append @state mu = mu(-1) + beta(-1)
ss_clothing.append @state beta = beta(-1) + [var=exp(c(5))]
ss_clothing.ml

sspace ss_communication
ss_communication.append @signal  communication = mu
ss_communication.append @state mu = mu(-1) + beta(-1) + [var=exp(c(6))]
ss_communication.append @state beta = beta(-1)
ss_communication.ml

sspace ss_education
ss_education.append @signal  education = mu
ss_education.append @state mu = mu(-1) + beta(-1) + [var=exp(c(7))]
ss_education.append @state beta = beta(-1)
ss_education.ml

sspace ss_food
ss_food.append @signal food = mu
ss_food.append @state mu = mu(-1) + beta(-1) + [var=exp(c(8))]
ss_food.append @state beta = beta(-1)
ss_food.ml

sspace ss_furnishing
ss_furnishing.append @signal  furnishing = mu
ss_furnishing.append @state mu = mu(-1) + [var=exp(c(9))]
ss_furnishing.ml

sspace ss_health
ss_health.append @signal  health = mu
ss_health.append @state mu = mu(-1) + beta(-1) + [var=exp(c(11))]
ss_health.append @state beta = beta(-1)
ss_health.ml

sspace ss_housing
ss_housing.append @signal housing = mu
ss_housing.append @state mu = mu(-1)+beta(-1) + [var=exp(c(13))]
ss_housing.append @state beta = beta(-1) + [var=exp(c(14))]
ss_housing.ml

sspace ss_misc
ss_misc.append @signal  miscellaneous = mu + beta + [var=exp(c(15))]
ss_misc.append @state mu = mu(-1) + beta(-1) + [var=exp(c(16))]
ss_misc.append @state beta = beta(-1)
ss_misc.ml

sspace ss_recreation
ss_recreation.append @signal  recreation = mu + [var=exp(c(18))]
ss_recreation.append @state mu = mu(-1) + beta(-1)
```

```
ss_recreation.append @state beta = beta(-1)
ss_recreation.ml

sspace ss_restaurants
ss_restaurants.append @signal  restaurants = mu
ss_restaurants.append @state mu = mu(-1) +  [var=exp(c(20))]
ss_restaurants.ml

sspace ss_transport
ss_transport.append @signal transport = mu + psi
ss_transport.append @state mu = mu(-1) + beta(-1)
ss_transport.append @state beta = beta(-1) + [var=exp(c(22))]
ss_transport.append @state psi = c(23)*cos(c(24))*psi(-1) + c(23)*sin(c(24))*psistar(-1) + [var=exp(c(25))]
ss_transport.append @state psistar = -c(23)*sin(c(24))*psi(-1) + c(23)*cos(c(24))*psistar(-1) + [var=exp(c(25))]
ss_transport.ml
```

B-2 State Space Forecasts of the 12 CPI components

```
smpl 2017m9 2017m12

ss_transport.forecast @signal ss_trans_f @signalse ss_trans_se
group sstrans ss_trans_f (ss_trans_f+ss_trans_se) (ss_trans_f-ss_trans_se)

ss_furnishing.forecast @signal ss_furn_f @signalse ss_furn_se
group ssfurn ss_furn_f (ss_furn_f+ss_furn_se) (ss_furn_f-ss_furn_se)

ss_food.forecast @signal ss_food_f @signalse ss_food_se
group ssfood ss_food_f (ss_food_f+ss_food_se) (ss_food_f-ss_food_se)

ss_housing.forecast @signal ss_hous_f @signalse ss_hous_se
group sshous ss_hous_f (ss_hous_f+ss_hous_se) (ss_hous_f-ss_hous_se)

ss_health.forecast @signal ss_health_f @signalse ss_health_se
group sshealth ss_health_f (ss_health_f+ss_health_se) (ss_health_f-ss_health_se)

ss_misc.forecast @signal ss_misc_f @signalse ss_misc_se
group ssmisc ss_misc_f (ss_misc_f+ss_misc_se) (ss_misc_f-ss_misc_se)

ss_recreation.forecast @signal ss_rec_f @signalse ss_rec_se
group ssrec ss_rec_f (ss_rec_f+ss_rec_se) (ss_rec_f-ss_rec_se)

ss_clothing.forecast @signal ss_cloth_f @signalse ss_cloth_se
group sscloth ss_cloth_f (ss_cloth_f+ss_cloth_se) (ss_cloth_f-ss_cloth_se)

ss_alcoholic.forecast @signal ss_alc_f @signalse ss_alc_se
group ssalc ss_alc_f (ss_alc_f+ss_alc_se) (ss_alc_f-ss_alc_se)

ss_restaurants.forecast @signal ss_rest_f @signalse ss_rest_se
group ssrest ss_rest_f (ss_rest_f+ss_rest_se) (ss_rest_f-ss_rest_se)

ss_education.forecast @signal ss_edu_f @signalse ss_edu_se
group ssedu ss_edu_f (ss_edu_f+ss_edu_se) (ss_edu_f-ss_edu_se)

ss_communication.forecast @signal ss_com_f @signalse ss_com_se
group sscom ss_com_f (ss_com_f+ss_com_se) (ss_com_f-ss_com_se)
```

B-3 State Space Forecast of the Headline CPI

```
weights.fill 27.38,4.85,5.31,20.75,3.75,1.33,12.45,3.14,3.07,2.75,8.82,6.39

model stif_ss

stif_ss.append composite_ss = (weights(1)*ss_food_f + weights(2)*ss_alc_f + weights(3)*ss_cloth_f +
weights(4)*ss_hous_f + weights(5)*ss_furn_f + weights(6)*ss_health_f + weights(7)*ss_trans_f +
```

weights(8)*ss_com_f + weights(9)*ss_rec_f + weights(10)*ss_edu_f + weights(11)*ss_rest_f + weights(12)*ss_misc_f)/100

smpl 2004m01 2017m12
stif_ss.solve

smpl 2005m01 2017m12
genr dcpi_ss_0 = 100*(composite_ss_0-composite_ss_0(-12))/composite_ss_0(-12)

Appendix C: Some results from FPAS

C-1 Initial conditions & Forecasts

Nominal Interest Rates

		17Q1	17Q2	17Q3	17Q4	18Q1	18Q2	18Q3	18Q4	19Q1	19Q2	19Q3	19Q4	20Q1	20Q2	20Q3
Policy rate	% p.a.	5.2	4.5	6.0	5.3	4.8	4.5	4.3	4.2	4.2	4.3	4.4	4.5	4.6	4.7	4.9
Neutral policy rate	% p.a.	5.6	5.6	5.5	5.4	5.4	5.3	5.2	5.2	5.1	5.0	5.0	4.9	4.9	4.8	4.8
91D-T bill rate	% p.a.	9.2	9.0	8.0	7.1	6.5	6.1	5.9	5.8	5.8	5.8	5.9	6.0	6.1	6.2	6.4
Interbank rate	% p.a.	6.4	6.3	5.7	5.7	5.7	5.6	5.6	5.6	5.7	5.7	5.8	5.9	6.1	6.2	6.4
US Fed Funds Rate	% p.a.	0.7	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.8	1.9	2.1	2.2	2.4	2.5

Nominal exchange rates

		17Q1	17Q2	17Q3	17Q4	18Q1	18Q2	18Q3	18Q4	19Q1	19Q2	19Q3	19Q4	20Q1	20Q2	20Q3
Nominal FX rate	level	822.9	827.8	832.0	837.8	843.6	849.4	855.1	861.0	866.9	873.0	879.2	885.5	892.0	898.7	905.6
	% YoY	8.5	6.7	4.1	2.8	2.5	2.6	2.8	2.8	2.8	2.8	2.8	2.8	2.9	2.9	3.0
	% QoQ ann.	3.8	2.4	2.0	2.8	2.8	2.8	2.7	2.8	2.8	2.8	2.9	2.9	3.0	3.0	3.1

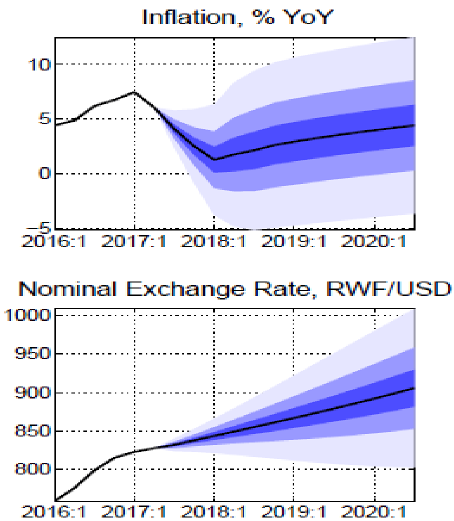
CPI Inflation

		17Q1	17Q2	17Q3	17Q4	18Q1	18Q2	18Q3	18Q4	19Q1	19Q2	19Q3	19Q4	20Q1	20Q2	20Q3
Inflation target	% YoY	4.2	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1
CPI Headline Inflation	% YoY	7.7	6.2	4.2	2.5	1.3	1.8	2.1	2.6	3.0	3.3	3.5	3.8	4.0	4.3	4.5
	% QoQ ann.	7.2	0.5	1.3	1.2	2.1	2.5	2.8	3.1	3.4	3.7	3.9	4.2	4.4	4.6	4.8
CPI Core Inflation	% QoQ ann.	5.1	12.6	3.5	1.9	1.2	1.0	1.2	1.7	2.2	2.6	3.0	3.4	3.6	3.9	4.1
CPI Ex-Core Inflation	% QoQ ann.	13.7	−28.4	−5.0	−1.0	4.9	7.1	7.6	7.5	7.2	6.8	6.6	6.6	6.7	6.8	7.0

Real GDP

		17Q1	17Q2	17Q3	17Q4	18Q1	18Q2	18Q3	18Q4	19Q1	19Q2	19Q3	19Q4	20Q1	20Q2	20Q3
GDP	% YoY	1.6	4.0	4.8	5.9	6.1	5.3	5.6	5.8	6.0	6.1	6.1	6.1	6.2	6.3	6.4
	% QoQ ann.	4.7	12.4	4.9	5.4	5.3	5.7	6.0	6.1	6.1	6.1	6.1	6.2	6.4	6.6	6.6
GDP Agric.	% YoY	2.5	5.7	6.3	5.3	3.6	3.3	4.1	4.5	4.8	4.9	5.1	5.1	5.2	5.3	5.3
GDP Non-Agric.	% YoY	1.3	3.4	4.5	6.3	6.9	6.2	6.3	6.3	6.5	6.6	6.5	6.5	6.6	6.7	6.9
Potential GDP growth	% YoY	4.7	4.2	4.2	4.8	5.3	5.3	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.1	6.2
	% QoQ ann.	3.4	5.5	5.1	5.3	5.4	5.6	5.7	5.8	5.9	6.0	6.0	6.1	6.2	6.2	6.2
Output gap (OG)	%	−1.1	−0.3	−0.3	−0.3	−0.3	−0.3	−0.2	−0.1	−0.1	−0.1	−0.1	−0.0	0.0	0.1	0.2

C-2 Fan-charts for key macroeconomic variables



CENTRAL BANK COMMUNICATION AS A POLICY TOOL UNDER THE PRICE BASED MONETARY POLICY

Samuel BAKER[11] **Christian NYALIHAMA**[12]

[11] Samuel Baker is an Economist in the Communication Division at National Bank of Rwanda

[12] Christian Nyalihama is a Principal Economist in the Department of Research at National Bank of Rwanda

ABSTRACT

In December 2018, National Bank of Rwanda will transition from a monetary targeting to a price-based monetary policy framework. Under the price-based policy framework, which is a forward-looking approach, it is argued that central bank communication is key for policy effectiveness.

Over the last decade, central bank communication has grown to become an important aspect of monetary policy. There is now a growing literature examining the role of this communication in policy effectiveness. This paper therefore briefly summarizes this literature. The review suggests that under forward-looking, price-based monetary policy frameworks, central bank communication is an important and powerful aspect of the central bank's toolkit since it has a potential to influence market expectations and enhance the transmission mechanism of monetary policy, thereby helping central banks to achieve their macroeconomic objectives. In addition to the review, this paper tries to reassess the effectiveness of BNR communication. The assessment indicates that BNR communication helps to reduce volatility of interbank rates and exchange rates in Rwanda.

I. INTRODUCTION

For most of the history of central banks, opaqueness has been deeply entrenched in their essence (Haldane, 2017). Greenspan (1988) once noted that: “I guess I should warn you, if I turn out to be particularly clear, you‘ve probably misunderstood what I said”.

At the time, central banks were never to be understood by anyone in the public, they were secretive and highly technical in their language. This prevailing quintessence was well captured by the job description provided to the Bank of England’s first press officer: “keep the Bank out of the press and the press out of the Bank” (Woodford, 2005). At the time, central banking was a mystery and central bankers guarded this mystique as essential to their success (Woodford, 2005).

The late 1990s were marked with a shift in the view of how central banks should interact with the public. Blinder (1998) argued that greater openness might actually improve the efficiency of monetary policy, because expectations about future central bank behavior provide the essential link between short-term rates and long-term rates. Evidence from research suggests that communication has become a powerful tool in monetary policy conduct, notably by influencing economic agents’ expectations.

In recent years, the National bank of Rwanda (BNR) continuously strived to enhance the role of communication in monetary policy through various channels, including press conferences, monetary policy committee (MPC) press releases, monetary policy and financial stability statement (MPFSS). These channels are meant to explain the rationale of its policy and give some kind of forward guidance to markets. Nevertheless, communication for monetary policy in Rwanda is relatively recent compared to central banks in developed countries.

The BNR is currently in a process of modernizing its policy framework from monetary targeting to price-based monetary policy where the role played by communication is more prominent. Hence, the present paper reviews the existing literature on the role of communication in monetary policy and reassesses the case of Rwanda, building on a recent article by Karangwa *et al.* (2017) and using a larger sample period with most recent data. Results from EGARCH and TGARCH models support previous evidence on effectiveness of BNR communication as it contributes to reducing the volatility in interbank rates and exchange rates.

The next section presents the literature on central bank communication and monetary policy. Section 3 proceeds with central bank communication in practice. Section 4 re-examines the effectiveness of BNR communication. The last section concludes the study.

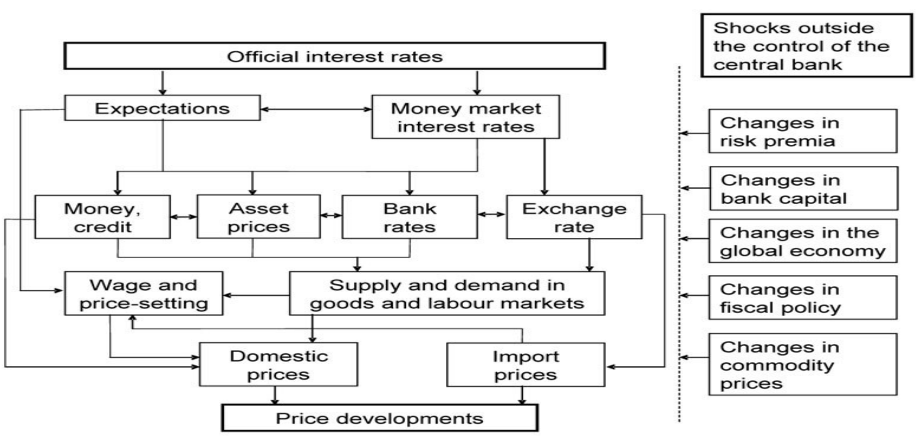
II. LITERATURE ON CENTRAL BANK COMMUNICATION AND MONETARY POLICY

It is widely held that central bank communication influences monetary policy transmission through expected future short-term rates that influence the long-term path of interest rates and the price of long-term financial assets. When the central bank can affect the expectations of future short-term rates by economic agents, it can ultimately affect economic activity and inflation path.

Private sector expectations reinforce the strength of different transmission channels of monetary policy, and central bank communication strategy plays a key role (Woodford, 2001). This expectations channel works via economic agents' expectations of future short-term rates which in turn affect long term rates and the later have an effect on exchange rates, assets pricing, economic activity and inflation. Although the central bank usually only has a control on short-term rates, it has to communicate clearly the medium term path of interest rates in order to affect long-term rates.

The chart below illustrates the monetary policy transmission mechanism and shows the role played by expectations.

Figure 1. The transmission mechanism of monetary policy



Source: ECB (2011)

Longer-term interest rates depend in part on market expectations about the future course of short-term rates. Central bank communication on official interest rate changes, therefore, influences the expectation formation on medium and long-term interest rates. Monetary policy communication can also help to guide economic agents' expectations of future inflation and thus influence price developments.

Currently, it is widely accepted that the ability of a central bank to affect the economy do not simply depend on current level of interest rates but instead depends on the ability by the central bank to influence market expectations about the future path of interest rates (Blinder *et al.,* 2008).

In the framework suggested by Blinder *et al.* (2008), medium and long term rates strongly depend on economic agents' expectations of future central bank policy, so that a given day rate is approximated as the average of today expectations of future overnight rates (re_t) plus a term premium (αn) and an error term.

$$Rt = \alpha n + (1/n)(rt + re\ t{+}1 + re\ t{+}2 + \ldots\ re\ t{+}n{-}1) + \varepsilon 1t, \qquad (1)$$

With R rt is the current overnight rate, re t+1 is today expectation of tomorrow's overnight rate (and so on for t+2, t+3,...), αn is a term premium, and ε1t the error term (Blinder *et al.,* 2008).

Blinder *et al.* (2008) highlighted the role of communication in a simple new Keynesian macroeconomic framework with aggregate demand Phillips curve and central bank reaction function where short-term rates, long-term rates, inflation expectation, output gap and inflation deviation from the target play an important role. In a stationary environment with unchanging policy rule, central bank communication would be redundant. However, this is less likely in real world where there are asymmetric information and non-rational expectations. Hence, central bank communication matters (Blinder *et al.,* 2008).

In addition, if economic agents have to estimate the central bank reaction function themselves, the learning process itself affect agents behavior and it is not guaranteed that the economy will converge to rational expectation equilibrium. Therefore, effective communication from the central bank can help to prevent that situation where agents guess what the central bank reaction function will be.

Rather, with clear central bank communication, actions become more predictable to the markets. As a result, it helps to anchor agents' expectations, thereby creating a virtuous circle, which reinforces policy effectiveness in managing the economy (Blinder *et al.,* 2008).

Woodford (2001) supported this view, arguing that central bank transparency is indeed valuable for the effective conduct of monetary policy. Ehrmann and Fratzscher (2005) also note that central bank communication and credibility are fundamental in successfully achieving its mission, namely price stability or macroeconomic stability.

For example, a reduction in key interest rate will not cause long-term interest rates in the capital market to decline as well, if it is thought that the expansionary monetary policy will cause inflation to rise in future. Under such circumstances, investors will factor the higher inflation rates expected, into the returns they expect to receive for providing debt capital over an extended period. Enterprises setting prices and social partners negotiating wages act in much the same way. They do not respond to changes in the supply and demand conditions in the market but act pre-emptively, drawing on their expectations of future inflation rates based on past experience. Central banks can therefore influence this behavior through clear and credible communication because this would give economic agents no reason to expect a different scenario from what the central bank is communicating.

III. CENTRAL BANK COMMUNICATION: PRACTICE

3.1. What is central bank communication?

Blinder *et al.* (2008) defines central bank communication as "the provision of information by the central bank to the public regarding such matters as the objectives of monetary policy, the monetary policy strategy, the economic outlook, and the outlook for future policy decisions".

It is argued that for monetary policy to be effective, it is important for the public to understand the central bank's actions, to the greatest extent possible (Haldane, 2017). The eff ectiveness of changes in central-bank policy in influencing behavior of economic agents is to a large extent dependent on how the public perceive or understand what the changes mean for them and are able to comprehend the messages from the central bank.

As such, it is key that the central bank not only communicates its action clearly to influence expectations but also obtain credibility in the eyes of the public. Better information on the part of market participants about central bank actions and intentions should increase the degree to which central bank policy decisions can actually affect these expectations, and so increase the effectiveness of monetary policy.

When the private sector fully understands the significance of current developments for future policy, markets can also, to a large extent, do the central bank's work (Woodford, 2005). Thus, the public's understanding not only of what the central bank is currently doing, but also of what can be expected to do in the future, is important for the effectiveness of policy.

3.2. What do central banks communicate

Although central bank transparency is essential, central banks have to decide what to communicate and why. This is because these institutions deal with so much information, which may not all be necessary for the public.

Among others, central banks have to communicate the following, as suggested by Woodford (2005) and other researchers.

3.2.1. Interpretation of economic conditions

In their communication, central banks must talk about the economic outlook, by explaining their views on current economic developments and the outlook, and the role the central bank policy will play in the future outlook.

3.2.2. Content of policy decisions

Central banks must communicate to the public, official decisions taken by committees (such as the Monetary Policy Committee) on official operating targets such as interest rates or monetary aggregates. In announcing these decisions, central banks must also explain the rationale for the decisions, for a better understanding by the public.

3.2.3. Strategy guiding the central bank's policy decisions

Central banks should also describe the strategy used to guide policy decisions. At times, the strategy includes communicating the analysis that will inform future decisions, and the foundations upon which these decisions will be based.

3.2.4. Outlook for future policy

This is a statement on outlook of future policy, although according to Woodford (2005), there was much debate on this. This is very important particularly because it helps to provide a view among the public, on how monetary policy will likely evolve in future. Since central bank actions are mostly forward-looking, communicating the strategy on the path of the monetary policy stance helps to anchor expectations on the outlook.

3.3. Channels for central bank communication

Central banks often announce policy changes on websites and newswires. As such, this helps to quickly transmit decisions, which helps to level the playing field for market participants.

Some central banks also organize press conferences after policy decisions have been made. Press conferences are a more flexible medium of communications, through which finer lines of reasoning can be provided. During these press conferences, the Governor speaks for the central bank and there is always a question and answer session, where questions from the media are answered by the panel of top executives at the central banks.

Empirical work carried out on the European Central Bank's (ECB) communications framework has shown that press conferences have a strong impact on the level of financial variables than corresponding policy decisions, which shows that they are an efficient means of transmitting new information (Ehrmann and Fratzscher, 2007).

In addition to press conferences, some central banks also organize public forums, in which representatives of the central banks gather to meet members of the public in different categories, such as bank CEO's, students, members of the civil society among others, to explain the decisions and actions of the central bank and the rationale for such decisions.

3.4. Central bank communication: The experience in advanced countries

Although many central banks share similar policy objectives, the evolution of central bank communication has seen different central banks implement different communication policies. Blinder *et al*'s (2008) framework (described in the preceding section) shows that the vector of communication signals takes different forms in different times and places.

According to Blinder *et al*. (2008) and Woodford (2005), central banks communication is essentially about four different aspects of monetary policy namely:

- The overall policy objectives and strategy;
- The motives behind a policy decision;

- The economic outlook;
- The outlook for future monetary policy decisions.

As previously indicated, transparency on the central bank policy rule helps to anchor inflation expectations, thereby mitigating some shocks and contributing to stable inflation. This is more important in forward-looking framework such as inflation-targeting or price-based monetary policy framework.

Nowadays, central banks communicate to the public their monetary policy decision on the same day the decisions are taken. This is fundamental because it reduces noise and public uncertainties and enhance monetary policy efficiency. Many central banks release press statements and organize press conferences after monetary policy decisions. Nevertheless, what distinguishes some central banks from others is the level of information disclosure. For instance, the Fed and ECB release minutes and vote records whereas ECB does not releases minutes.

Another key aspect is the extent to which central banks communicate on what they believe to be the outlook of the economy. The assessment of central banks on future inflation, economic activities, output gaps will likely guide future policy decisions and interest rate paths, which are essential in anchoring agent expectations and reinforcing policy transmission.

Most of inflation-targeting countries have that forward-looking information in their communication often with some probability distribution in form of fan charts. Other modern central banks also frequently publish their forecast on inflation and output. In some countries, such as New Zealand, Norway, the Czech Republic, Sweden, and Hungary go farther and even publish estimates of output gaps (Blinder *et al.,* 2008).

Forward guidance on future monetary policy decisions is another important aspect of central banks communication. On this also, central banks differs on the extent to which they are explicit.

3.5. Communication at the National Bank of Rwanda

As the BNR transitions from the monetary targeting policy framework to a more forward looking price-based monetary policy framework, communication to economic agents will be a very important tool in the success of policy and other central bank actions.

In the new framework, the nominal anchor would be "a price" (i.e. interest rate) instead of the quantity of money as in the monetary targeting framework. This new framework is forward-looking in the sense that policy decisions will be anticipating future movement in macroeconomic variables. These variables include expected inflation vis-a-vis the target, projected output gap and an interest rate path to bring inflation to its target in medium term.

The projected interest rate path will be consistent with BNR inflation target and other key macro variables. The BNR will be intervening on money markets to influence the interbank rate in line with the policy stance.

Effective communication on policy stance and on projected path of future short-term rates should therefore help in managing economic agents' expectations of future interest rates, which ultimately affects interest rates for longer maturities and reinforce the transmission channels (Berg *et al.,* 2013).

To prepare for this transition, the BNR has put in place communication practices that allows it to reach out to the wider public through various channels.

BNR uses several channels to communicate to the markets and these are:

i. Press releases on MPC decisions after every MPC meeting;
ii. The Governor's bi-annual Monetary Policy and Financial Stability Statements followed by similar statements across universities and provinces around the country;
iii. Staff papers published in BNR Economic Review to articulate the views and forecasts of BNR staff on the wider economy;
iv. BNR Research Day to disseminate the BNR staffs' research findings.
v. BNR website (www.bnr.rw) is a source of most information including monetary and financial data, and articles on topical issues especially those published in the Rwandan Banker;
vi. Press conferences, stakeholder forums, quarterly meetings between BNR and CEOs of banks and a feedback mechanism through the Communication Unit that facilitates information requests from the public; and
vii. Social media sites that are leveraged upon for collating public views.

In 2018, the BNR developed channels such as BNREngage program, through which it engages the public and markets on an ongoing basis and is available, where possible, to meet with a constant stream of domestic and foreign investors in the country. BNREngage is a channel through which the bank is reaching out to the public to explain the most complex economic concepts in a simple and non-technical way but also encouraging the public to engage the bank, ask questions on what they do not understand so that explanations can be given.

The main purpose for the program is that Rwandan public of all ages can learn more about what BNR does and constantly interact with BNR, which should increase the level of economic literacy and as a result strengthen the expectations channel of monetary policy, where communication from the central bank will successfully influence expectations.

Table 1: Key BNR Communication tools and frequency of use

Communication tool	*Frequency*
MPC Press Release	Quarterly
MPC working document	Quarterly
Monetary Policy and Financial Stability Statement	Bi-annual
Quarterly inflation report	Quarterly
Economic Review: Research papers	bi-annual
Meeting with CEOs of Banks	Quarterly
The Banker	Bi-annual
News/ data on BNR website	Regular

When BNR started focusing on increasing open communication to the public about its policy actions, a mechanism was put in place to track feedback thereof. As an example, the BNR's Monetary Policy and Research Directorate distributes a small questionnaire to the participants of the Monetary Policy and Financial Stability Statement (henceforth MPFSS) and results are used for decision making. This questionnaire focuses on the quality of the contents of the MPFSS, the kind of information that can be added to the MPFSS to meet the expectations of the public, how information in the MPFSS has been used and how BNR can be judged in terms of performing its core mandate.

Generally, an average of 99% of the respondents in the 2015-2018 period confirmed that the BNR's performance against its core mandate can been judged as satisfactory or above (that is, satisfactory, very good and excellent).

VII. MEASURING THE EFFECTIVENESS OF CENTRAL BANK COMMUNICATION

As the key objective of central bank communication is to manage economic agent's expectations, usually manifested in financial markets, central banks generally observe financial markets in order to assess economic agent's feedbacks.

Empirically, volatility in prices (interest rates) and in transactions volume are the main indicators observed. Therefore, volatility models in the form of GARCH model and its variants can help to assess the effectiveness of central bank communication in affecting market interest rates, as in most of study cases reviewed.

In practice, GARCH model help to model changing variance (volatility) of a variable of interest. In the case of monetary policy, most of the studies considered money markets rate and explanatory variables included a variable measuring central bank communication, mostly in form of dummy variable.

For the case of Mexico, as an example, Garcia-Herrero *et al.* (2015) used various GARCH models (GARCH, EGARCH, TGARCH) to assess (i) volatility of log range of overnight repo rates following central bank communication, (ii) daily change in volume of repos and (iii) whether the markets understood Bank of Mexico message by modelling intraday change in repo rates. The overall results indicate that money markets understand and react to central bank communication in Mexico. Similarly, Horvath and Karas (2013) also found that financial markets responds to central bank communication in Czech Republic as the latter affect both level and volatility of interest rates as shown by their TGARCH model.

For the case of Rwanda, Karangwa *et al.* (2017) borrowed from the methodology used by Horvath and Karas (2013) and assessed the effect of BNR communication on volatility of short-term interest rates and exchange rates in Rwanda, and found that increased communication is expected to have a measurable impact on interest rates and the exchange rate.

On interest rates, they defined a dummy for BNR communication where = 1 stands for the quarter during which BNR communicated its monetary policy committee decision to the public and 0 =otherwise and estimated a TGARCH model.

Their results indicated that BNR communication has helped to reduce volatility in interbank rates. On exchange rates, they used a dummy for central bank intervention on the exchange rate markets as a signal for the current and expected exchange rate pressure. Their results from EGARCH model also suggested that BNR communication has contributed to smooth out excessive volatility on exchange rate markets.

Their results from the analysis revealed that in the interbank volatility equation, increased BNR communication of its policy stance has helped to reduce volatility in interest rates. Similar their findings for the volatility equation of the exchange rate showed that BNR interventions, as a measure of central bank actions or signal, has had a huge impact in terms of stabilizing the exchange rate in Rwanda.

Using the same methodology with a larger sample period that comprise most recent data, our results are almost similar to what Karangwa *et al.* (2017) found. The effect of BNR communication on reducing interest rates volatility is relatively stronger, whereas the effect of BNR actions or signal on stabilizing exchange rate are somehow moderated relative to Karangwa *et al*'s (2017) results.

Table 2: TGARCH results for the interbank rate

Dependent Variable: D(IR)				
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-1)^2*(RESID(-1)<0) + C(5)*GARCH(-1) + C(6)*DUMMY				
Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
C	-0.0366	0.0395	-0.9260	0.3544
Variance Equation				
C	0.1516	0.0214	7.0679	0.0000
RESID(-1)^2	0.5982	0.1323	4.5202	0.0000
RESID(-1)^2*(RESID(-1)<0)	0.6358	0.2602	2.4431	0.0146
GARCH(-1)	0.2155	0.0464	4.6394	0.0000
DUMMY	-0.0899	0.0342	-2.6297	0.0085

Considering the fact that BNR is in the process of moving from monetary targeting framework to a price-based framework where money market rates play a fundamental role, these results are encouraging. BNR communication does have considerable influence on money markets. Hence, BNR should continue to enrich its communication to complement its monetary policy actions.

Table 3: EGARCH results for the exchange rate

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DUM2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	1.680	0.157	10.731	0.000
		Variance Equation		
C(2)	1.953	0.926	2.109	0.035
C(3)	0.709	0.206	3.439	0.001
C(4)	0.244	0.147	1.663	0.096
C(5)	0.283	0.179	1.585	0.113
C(6)	-1.192	0.752	-1.586	0.113

Another implication of these results is that, since markets are at some extent listening to BNR communication, it is important for BNR to be transparent and most importantly consistent in its message, to avoid any risk of misleading the markets.

CONCLUSION

The global economic environment has undergone a shift that has created a need for central banks to uphold transparency on how they operate, in order to achieve their policy objectives. With transparency has come the need for increased communication with markets and the public. In a simple macroeconomic framework designed to illustrate the role of central bank communication under price-based monetary policy frameworks, this paper has shown that indeed, central bank communication is a key policy tool because it helps to influence expectations. This expectations channel works via economic agents expectations of future short-term rates which affect long term rates and the later have an effect on exchange rates, assets pricing, economic activity and inflation. Longer-term interest rates depend in part on market expectations about the future course of short-term rates.

Central bank communication on official interest changes therefore influences the expectation formation on medium and long-term interest rates. Monetary policy communication also helps to guide economic agents' expectations of future inflation and thus influence price developments. Although the central bank usually has a control on only short-term rates, it has to clearly, communicate its actions to the public, to ensure that changes in official rates transmit through to the real economy.

Therefore, as BNR transitions from a monetary targeting to a forward-looking price-based monetary policy framework, a focus on successful implementation of a strong policy communication strategy is key for policy effectiveness. Empirical evidences indicate that BNR communication has some influences on money markets in Rwanda as it help to reduce volatility of both interest rates and exchange rates.

Therefore, BNR should continue to improve and strengthen the function of policy communication, to ensure that markets as well the public fully understand any actions taken by the central bank. This will help to improve the transmission mechanism of monetary policy in Rwanda.

REFERENCES

Berg, A., Charry, L., Portillo, R. and Vlcek, J. 2013. "The Monetary Transmission Mechanism in the Tropics: A Narrative Approach." IMF working paper WP/13/197.IMF, Washington DC.

Bernanke, B. S. 2004. "Monetary Policy Alternatives at the Zero Bound: An Empirical Assessment." Brookings Papers on Economic Activity.

Blinder, A. S. 1998. "Central Banking in Theory and Practice." Massachusetts Institute of Technology Press. MIT, Boston, MA.

Blinder, A. S., Jansen, D. J., De Haan, J. and Ehrmann, M. 2008. "Central Bank Communication and Monetary Policy." ECB Working Paper, No. 898, Frankfurt, Germany.

ECB. 2011. "The monetary policy of the ECB." European Central Bank. Frankfurt, Germany.

Ehrmann, M. and Fratzscher, M. 2007. "Explaining monetary policy in press conferences." ECB Working Paper No. 767.Frankfurt, Germany.

Ehrmann, M. and Fratzscher, M. 2005. "How should central banks communicate?" ECB Working Paper No. 557. Frankfurt, Germany.

Garcia-Herrero, A., Girardin, E. and Lopez-Marmolejo, A. 2015. "Mexico's monetary policy communication and money markets." BBVA Working Paper Nº 15/15.

Greenspan, A. 1988. "Statement before the Committee on Banking, Housing and Urban Affairs." Board of Governors of the Federal Reserve.

Haldane, A. 2017. "A Little More Conversation; A Little Less Action." Transcript, *Federal Reserve Bank of San Francisco*, 31 March 2017.

Horváth, R. and Karas, P. 2013. "Central Bank Communication and Interest Rates: The Case of the Czech National Bank." *Czech Journal of Economics & Finance* Vol. 63 (5): 454-464.

Karangwa, M., Uwimpundu, D. and Sebera, P. 2017. "Impact of Central Bank communication on effectiveness of Monetary Policy in Rwanda." *BNR Economic Review* Vol 11: 25-54.

King, M. 2005. "Monetary policy – practice ahead of theory." transcript, *Cass Business School*, 17 May 2005..

Svensson, L. E. O. 2003. "What Is Wrong with Taylor Rules? Using Judgment in Monetary Policy through Targeting Rules." NBER Working Paper 9421. Cambridge, MA.

Woodford, M. 2005. “Central-Bank Communication and Policy Effectiveness”. In The Greenspan Era: Lessons for the Future. Kansas City: Federal Reserve Bank of Kansas City. Kansas City, MI.

Woodford, M. 2001. "The Taylor Rule and Optimal Monetary Policy." *American Economic Review* Vol. 91: 232-237.

National Bank of Rwanda
KN 6 AV. 4
P.O. Box: 531 Kigali, Rwanda
Tel: (+250) 788 199 000
Email: info@bnr.rw
Swiftcode: BNRWRWRW
Twitter: @CentralBankRw
Website: www.bnr.rw